PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY

OF GLASGOW.

VOL. IX.

MDCCCLXXIII.—MDCCCLXXV.

PUBLISHED FOR THE SOCIETY BY
JOHN SMITH AND SON,
129 WEST GEORGE STREET, GLASGOW.
1875.

5+

GLASGOW:
PRINTED BY BELL AND BAIN,
41 MITCHELL STREET.

CONTENTS OF VOLUME IX.

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

SEVENTY-FIRST SESSION.

I.—*On some Indications of a Daily Periodicity in the Vital Functions of Man.* By JAMES FINLAYSON, M.D., Fellow of the Faculty of Physicians and Surgeons, Glasgow.

[Read before the Society, December 3, 1873.]

PERIODICAL phenomena have long been favourite subjects of research on the part of physical philosophers, and in many instances—as, for example, in the daily periodicity of the Tides—a satisfactory explanation has been arrived at.

To the Physiologist, also, the idea of periodicity is no less familiar. The annual development of sexual activity in many of the lower animals, and the monthly recurrence of an analogous process in our own species, present well-known instances of a marked periodicity. The object of the present paper is to shew that a DAILY periodicity can also be traced in some of the most important functions of our economy, and that this daily oscillation is of such a character as to elude explanation by any of the obvious causes which have hitherto been suggested.

It is not necessary for the purpose of the present inquiry to define the exact significance of the phrase "Vital Functions." The phenomena about to be referred to in this paper are confessedly amongst the most important features of animal existence: they have been selected from others of perhaps equal importance, chiefly on account of their being susceptible of a satisfactory estimation and statement in a quantitative manner.

Before proceeding further, it should at once be mentioned that this subject has engaged the attention of Dr. Edward Smith. After communicating various papers to the Medico-Chirurgical and to the Royal Society, he summed up his results in a book, published in 1861, entitled, *Cyclical Changes.* In this work the "Daily Cycle," as he calls it, is considered in respect of the rate of Pulsation and Respiration, and the Excretion of Carbonic Acid and Urinary matter. The effect of fasting on these functions was also, to some extent, investigated. The results of Dr. Smith's laborious inquiry will be made use of in this paper; but since the date of his observations other investigations have been made; and while they confirm in large measure the results he arrived at, they correct some of his ideas, and seem to put the question on a more stable and somewhat different foundation. In this work Dr. Smith spoke of its being still a desideratum to determine experimentally the oscillations of temperature which occurred during the night and day in the human subject (p. 86), so that he could not incorporate in his book the results yielded by this method of inquiry.

The vast importance of the oscillation of the temperature, as expressing the resultant of the manifold operations going on in the human system, has of late years been more and more realised, and so we now possess very complete observations on this physiological point. A few years ago I had an opportunity of making a contribution to this part of the subject, as regards the diurnal variation of temperature observable in healthy children. The details of this inquiry, embracing about 300 observations, were communicated, in 1868, to the Medical Section of the Manchester Royal Institution, and they have since been published in full.* The general result (as shewn in the Diagram No. 1) may be expressed as indicating the existence of a minimum from about 10 P.M. to 3 A.M., of a gradual rise during the early morning hours, of a maximum during the day, and of a tolerably rapid fall during the early part of the evening. The average range of temperature thus described amounted to more than three degrees of Fahrenheit's scale. This range of normal temperature was regarded as so considerable, and the diminution in the evening so remarkable, that at first some doubts were not unnaturally expressed regarding the correctness of these conclusions; but further investigation of the subject, on the part of others, has confirmed the results then published.†

* "On the Normal Temperature in Children."—*Glasgow Medical Journal* Feb., 1869; also, in *Journal für Kinderkrankheiten, Erlangen,* June, 1869.

† "On the Temperature of the Human Body in Health," by Sydney Ringer,

If we compare the curve representing these observations on temperature with a curve from Dr. Smith's paper, derived from three days' observations of the pulse-rate in the case of a healthy child (*æt.* 6), we find that the pulse-curve (Diagram No. 2), although apparently more subject to disturbing influences, indicates a general and essential agreement with the other.

In the case of adults, the variations of the temperature and of the pulse-rate present a less range of oscillation, and the adult pulse occupies a somewhat lower level; but the daily oscillations are essentially similar in character.* I select for illustration the observations of Dr. Edward Smith on his own average pulse-rate (Diagram No. 4); the minimum observed by him during the hours immediately succeeding midnight is all the more instructive, as, during the three days of this inquiry, he was awake in the night as well as the day.†

The variations of the adult temperature might, in the present state of science, be illustrated by the laborious results of many inquirers, both English and foreign; but, for a special reason, the observations of Jürgensen,‡ which, indeed, agree in the main with those of other observers, seem to answer our present purpose best. These observations, like those in my own inquiry on children, were made in one of the internal cavities. They were, during the period of inquiry, exceedingly numerous, and the man while under observation remained in bed. The curve selected § shews the variation of temperature in the course of a single day and night; and except that the range is somewhat less, and the period of the evening decline and the morning ascent somewhat later, the essential features are identical with the children's average, as shewn

M.D., and the late Andrew Patrick Stuart.—*Proceedings of the Royal Society*, Feb. 11, 1869.

"Die normale Temperatur in Kindesalter," von Dr. C. Pilz (*Jahrb. f. Kinderheilk.* iv. 4, p. 414, 1871), Analysed in *Schmidt's Jahrbücher*, bd. 152; p. 177; and *Biennial Retrospect of Medicine*, Lond. 1873, p. 39.

* Dr. Edward Smith describes four periods, viz:—"*1st.* The minimum period or 'night,' from 1 to 5 A.M.; *2nd.* The maximum period or 'day,' from 9 A.M. to 9 P.M.; *3rd.* The 'morning,' ascent, from 5 to 10 A.M.; and, *4th.* The 'evening' descent, from 9 P.M. to 1 A.M."—*Medico-Chirurgical Transactions*, vol. xxxix., p. 42, Lond. 1856.

† Dr. Edward Smith—*Cyclical Changes*, Lond. 1861, pp. 6 and 99.

‡ Dr. Theod. Jürgensen. —*Deutsches Archiv f. klinische Medicin*, bd. iii. Leipz. 1867. Reprinted; *Die Körperwärme des gesunden Menschen.* Leipzig, 1873.

§ Man, *æt.* 42, Sept. 21, compiled from Tab. IV. and V. of Jürgensen's paper, already referred to.

in the other diagram. Disregarding, for our present purposes, the comparatively slight variations of the temperature during the day, we may again express the result, as shewing a minimum after midnight, a rise in the morning, a maximum during the day, and a decline in the evening. (Diagram No. 3.)

Leaving the temperature, and turning to one of the most important excretions, we find that the amount of urinary solids, when tabulated for the various hours of the day, shews an essentially similar variation. Dr. William Roberts* of Manchester has, amongst others, investigated this question; and although there is an inevitable slumping of the rate of secretion during the hours of sleep, his results, when reduced to the form of a curve (Diagram No. 5), are valuable for this inquiry. The description of the daily oscillation need not be repeated, as, indeed, the language just used with regard to the pulse and temperature adequately expresses it.

Dr. Edward Smith's investigation† of the excretion of urea at different hours of the day, agrees essentially with these results; and even when the diet was restricted to water only, without food of any kind, the usual daily range preserved its former character.

We thus find in three sets of phenomena, which are perhaps among the most important that belong to the animal economy—the Pulse, the Temperature, and the Urinary excretion—a well-marked daily range of variation. It starts from a minimum maintained from about midnight to the first few hours after it; rising gradually during the later hours of the morning, or in the course of the forenoon, it attains the maximum or maxima at some time during the course of the day, and declines again in the early evening, or at least before midnight. It is no part of our present purpose to discuss the interconnection of these functions, or to inquire which, if any, should be regarded as the primary phenomenon. We do not err in supposing that the various oscil-

* *Edinburgh Medical Journal*, March, 1860; also, *Urinary and Renal Diseases*, 2nd ed., Lond. 1872, p. 21. Average of seven days; solid matter calculated from specific gravity, taken with the specific gravity bottle.

† "The average hourly emission of urea was, on the whole day, 21·7 grains; during the night, 16·5 grains; before breakfast, 20·3 grains; and before mid-day, 25·5 grains. The decrease of the night was 24, and of the early morning, or 'basis quantity,' 6·4 per cent., whilst the increase to mid-day was 17½ per cent. . . . Water taken several times during a day of fasting caused the same hourly progression in the elimination of urea and urine as occurs with food, except that the changes were more rapid and the decrease at the end of the intervals greater."—Dr. Edward Smith on the "Elimination of Urea and Urinary Matter," *Proceedings of the Royal Society*, May 30, 1861, vol. xi., p. 216.

lations noticed are all manifestations of certain deep-seated changes in the human organism, occurring day by day in a rhythmical manner.

But it may occur to many that the explanation of all this lies on the surface. For, it may be said, the period of darkness bringing rest and sleep, reduces the animal functions to a minimum; the stimulation of the light and heat of a new day arouses the energies, and calls us forth to muscular exertion; the morning meal further heightens the play of the internal forces, and leads up to the maximum reached or maintained during the day; but this naturally begins to fade away as the chill and rest of another evening ushers in again our nightly sleep.

It remains now to point out that this explanation breaks down so completely, when analysed in detail, as to appear to be wholly untenable.

Of course, it is not asserted that the agencies just named have no influence on the course and activity of the vital functions. The influence of food-taking on the pulse-rate is most marked, and the accelerations thus caused are clearly shewn, as causing more or less disturbance, in the curves already referred to. The effect of muscular exercise on the animal heat is well known to all, and the rise of temperature produced in this way can be easily demonstrated by the thermometer. The amount of the urinary excretion (both fluid and solid) has been proved to depend more on the ingesta than on anything else. A careful survey, however, of these influences will shew that, potent though they are, they are totally inadequate to explain the periodical morning rise and evening fall already described.

1. The influence of the *Diurnal range in the temperature of the air* may at once be disposed of, when we find that in the extended observations of Dr. John Davy, on the heat of his body in this country, the temperature of his room was much higher at midnight than in the morning; but this did not prevent the usual decline of his own temperature in the course of the evening.*

2. The influence of *Daylight* has seemed to Dr. Edward Smith and others to coincide with and to account for the increased energy of the vital functions in the morning hours. This, however, has been satisfactorily disposed of by Dr. William Ogle. During one

* Dr. John Davy, *Physiological Researches*. London, 1863, p. 14:—

Average.	7-8 A.M.	3-4 P.M.	12 P.M.
Temperature of Body, . .	98°·74 F.	98°·52 F.	97°·92 F.
Temperature of Room, . .	50°·9	54°·7	62°

part of the observations published by him on his own temperature, he arranged to have his window shutters closely fastened, so as to exclude the action of this agency. This step, however, did not interfere with the rise of the temperature of the body at the usual hour in the morning.*

3. The influence of *Muscular exertion*, if not abolished, was reduced to a minimum by having the subjects of observation kept all day in bed, in at least some of the cases recorded in my paper on the temperature of children,† a restriction likewise carried out in those observations on the temperature of adults, already quoted from Jürgensen. But the course of the temperature, under such circumstances, proceeded as usual.

A further confirmation of the increased vital activity in the morning, independent of any disturbance from food or exercise, is incidentally supplied in the details of an experimental inquiry recently communicated by Dr. Parkes to the Royal Society. It was found, contrary to expectation, that, although the subject of observation was kept absolutely in bed and without fluids or solids of any kind till 10 A.M., the quantity of urine secreted from 8 to 10 always exceeded that secreted during the two preceding hours (6 to 8).‡

4. The influence of *Food* over this daily periodicity can scarcely be regarded as very potent, inasmuch as in the observations on children, already referred to, the temperature was found to fall rapidly after the evening meal, and then, reaching the minimum, to rise slowly, and to gain a very high standard before any more food was taken.

Additional confirmation is supplied by finding, as Jürgensen did, that during complete abstinence from food the daily course of the

* Dr. William Ogle, "On the Diurnal Variations in the Temperature of the Human Body in Health."—*St. George's Hospital Reports*, vol. i. London, 1866, pp. 229, 242.

† *Glasgow Medical Journal*, February, 1869.—Table XIII. For two days the child was in bed (and had been so for some time), and for the next two days she was up and moving about; the range of temperature was similar.

‡ Dr. Parkes, "Further Experiments on the Effect of Diet and Exercise on the Elimination of Nitrogen."—*Proceedings of the Royal Society*, March 2, 1871, pp. 351, 352.

	6-8 A.M.	8-10 A.M.
Amount of Urine in Cub. Centim., . . .	71·65	100·4

Dr. Parkes supposed the difference to be due to the influence of sleep, as the man slept from 6 to 8, but lay in bed awake from 8 to 10. This will be considered in the section (5) on sleep.

temperature* followed very much the same curve as it did during the previous days, with the usual diet.†

The duration of such starvation observations must of course be very limited in the human subject, so that it is perhaps fair, in this connection, to adduce the experimental researches of M. Chossat on animals. He found that starvation, pushed even to the length of causing the death of birds, did not, till quite near the fatal day, prevent the temperature of the animals from rallying each morning to near its normal amount from the depression of the previous night. The effect of starvation increased the amount of the usual depression at night, so that the daily rise every morning became all the more remarkable, as an evidence of its being due, under ordinary circumstances, to something else than the morning meal.‡

5. The influence of *Sleep* has been supposed to account for the difference between the average hourly quantity of urine secreted during the night and that secreted in the waking state, before breakfast. When, however, we consider that observations shew a gradual increase in the temperature and pulse-rate during the morning hours of sleep, it seems very doubtful whether this opinion can stand its ground. In the case both of the pulse and of the temperature (which are more within the reach of hourly observation), the diminution is seen to begin long before sleep occurs; and, in Dr. Edward Smith's observations on himself, the pulse-rate went down and kept down during the night, although he was then awake and engaged in making his hourly notes. The gradual rise of the temperature and the pulse-rate during sleep (as shewn in the observations on children, already quoted), taken along with the

* The observations were made on the same subject, as in the case of Diagram No. 3, and took place on the following day, viz., September 22. (See Tables V. and VI. of Jürgensen's paper.)

† See also Dr. Edward Smith, *Med.-Chir. Trans.*, vol. xxxix., p. 49.—Speaking of the pulse-rate during fasting, he says—"There was a manifest disposition in the pulse to rise at the customary hours of its rising, although in the absence of any usual cause for that rise. This was at the usual meal hours, as seen in every case."

Dr. Sydney Ringer's experiments seem to have negatived the idea of the diurnal variations being due to the food eaten.—*Proc. Royal Socy.*, February 11, 1869.

‡ M. Chossat, *Recherches Expérimentales sur l'Inanition.* Paris, 1843.

		Mid-Day.	Mid-Night.
Tab. No. 63,	Ordinary diet.—Average temperature of the Birds, . . .	42°·22 C.	41°·48 C.
Tab. No. 69, and 72,	Complete abstinence. — Average, omitting the last day of life, . .	41°·70 C.	38°·42 C.

above facts, seems to negative conclusively the influence of sleep as the cause of these periodical phenomena.*

A critical examination of the potent influences just enumerated seems to leave the periodicity in question unexplained, and, indeed, to bring out, in even greater relief, the rhythmical rise and fall of the vital functions day after day.

But there is another way to judge of this matter, viz.—not by the exaltation and diminution of the vital energies, but by their cessation. The question of the influence of the time of day in relation to Death has long engaged both popular and professional attention, and it has now been put on a satisfactory basis by the researches of Dr. Schneider and others on the Continent, and of Mr. West Watson in this country. Dr. Schneider tabulated the deaths in Berlin for five years, representing some 57,000 cases, and Mr. Watson tabulated 13,000 deaths, occurring in Glasgow in 1865, according to the hour at which they were reported as having taken place.

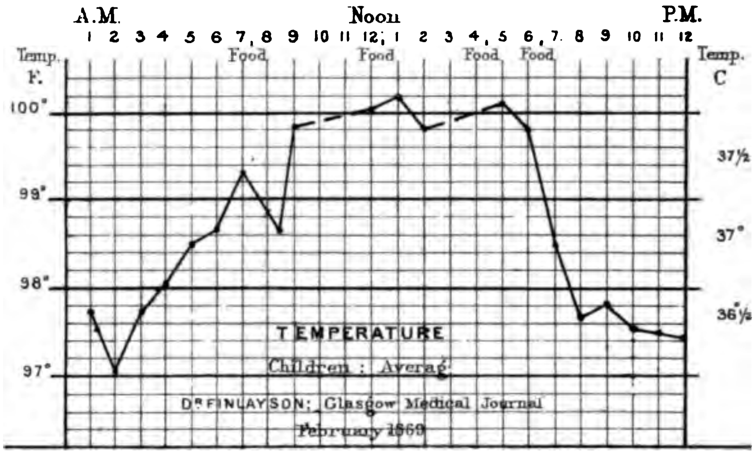
A striking feature in both tables, but one which seems, if we might so say, quite accidental in its character, is the high number of deaths recorded for 11 to 12 P.M., and the equally striking paucity for the succeeding hour, 12 P.M. to 1 A.M. When, however, these two sets of figures are put together, they mutually destroy the exceptional character given to the two hours in question.

Doubtless the explanation lies not in any special difference as regards the occurrence of deaths at the one hour, as compared with the other (a difference which seems altogether too abrupt and artificial to be in accordance with the gradual methods of nature), but in the difficulty arising from these two hours forming the border line of two separate days. The natural tendency is to avoid, if possible, the uncertainty and ambiguity which attaches (in this country at least) to speaking of an occurrence as happening, for example, at a quarter-past twelve this morning. The determination of the exact time of death is usually so much surrounded by uncertainties, from scientific, chronometric, and emotional causes, as to leave great room for variation to the extent of half an hour one way or another.

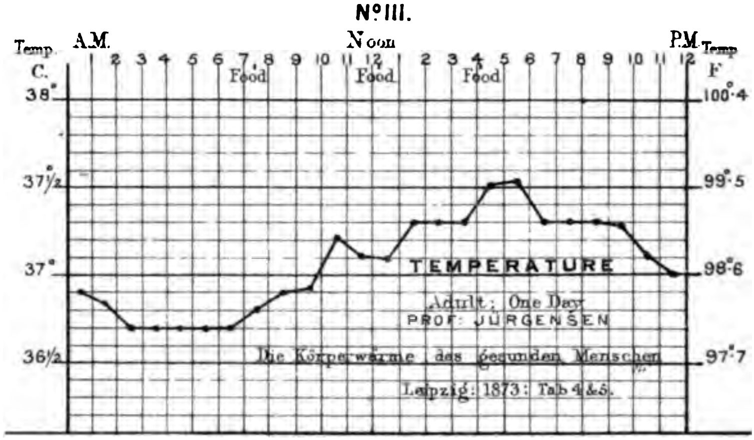
Ignoring, therefore, this sudden discrepancy between the last and

* v. Baerensprung (whose accuracy is well known) seems also to have arrived at this conclusion. The influence of dinner and sleep is, he says, only apparent. The temperature sinks, although we do not go to sleep, and sleeping during the day does not alter it. It rises at dinner-time, although the hour of eating is put off.—*Müller's Archiv.* Berlin, 1851, p. 163.

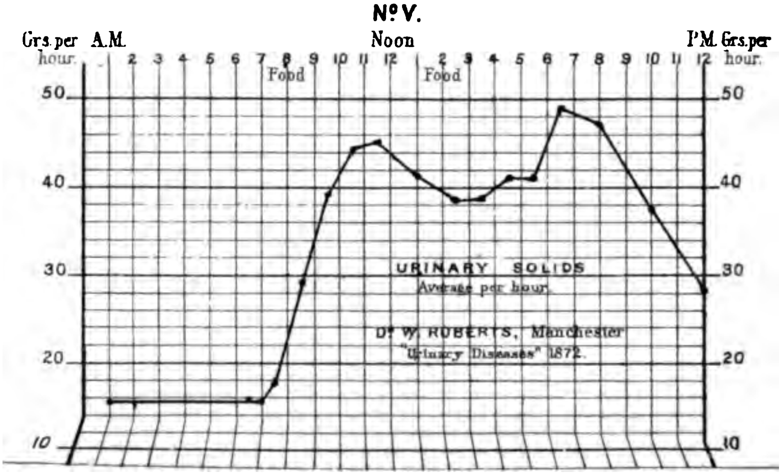
No. I.



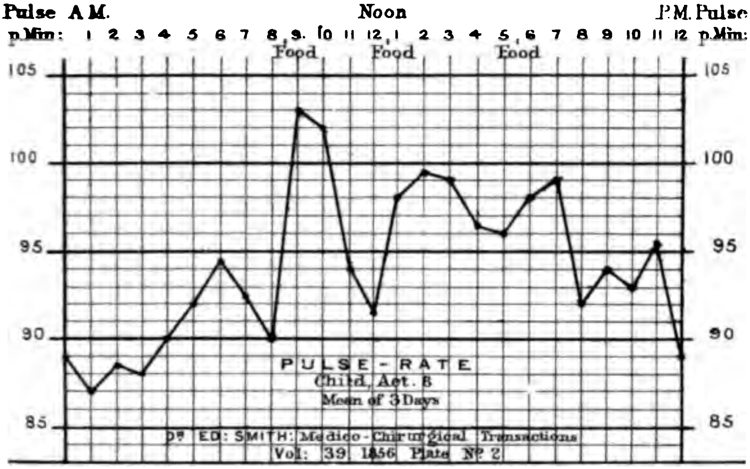
No. III.



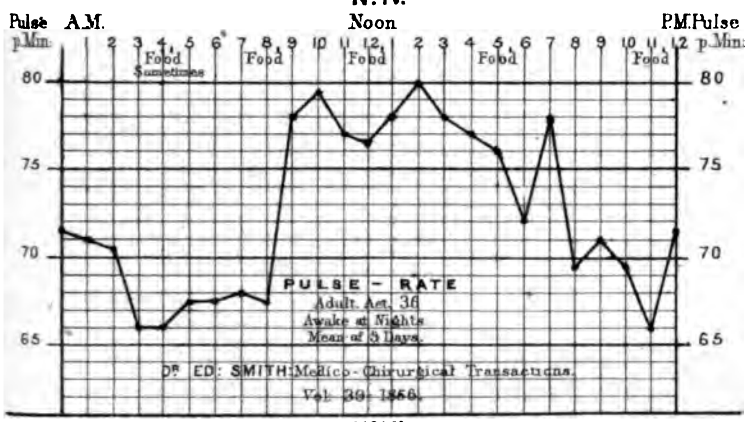
No. V.



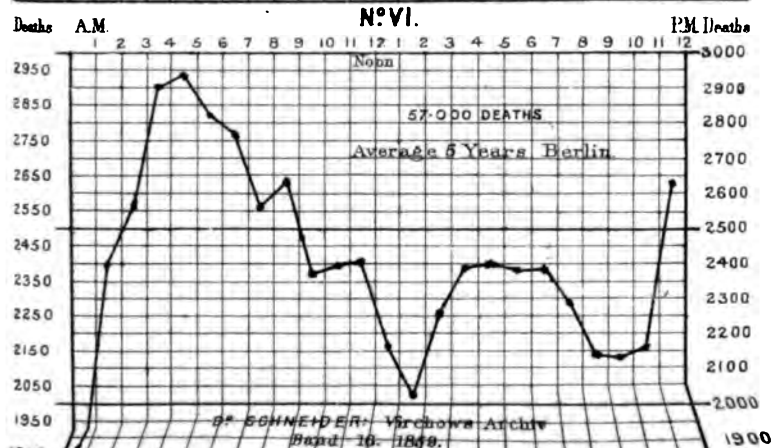
N.º II.



N.º IV.



N.º VI.



the first hour of the day, as attributable rather to moral causes than indicative of any actual fact, we find that the death curve (Diagram No. 6), shews an unmistakable maximum, gradually reached and consistently maintained, from 3 to 9 A.M., according to Schneider, and from 4 to 10 A.M., according to Watson.*

This maximum, indeed, is the only other peculiarity of much note. The period named, however, has been shewn to form a critical epoch in the various curves already discussed, being, in fact, the time of transition from the minimum of depression to the morning rise, which ushers in the period of maximum vitality. Hence we may either say, that the period of minimum vital energy, which exists during the first few hours after midnight, being deepened and perhaps prolonged, coincides with the summit of the death curve;† or, phrasing it otherwise, that the time having arrived for a fresh rallying of the vital energies for a new day, the dying are found to be unable to respond to the call, and so they perish in greatest numbers at the very hours in which the living are manifesting in every way a renewed vigour.

I might conclude with this crowning proof of the periodical influence at work in our daily life, but I venture to make a suggestion which, apart from any value it may possess as an explanation of the physiological cause of the phenomena, may serve at least to indicate the direction for further research.

It has occurred to many that in these periodical phenomena we have to do with a question of Habit. We are all familiar with the influence of Habit as connected with tendencies at certain hours to hunger and sleep. The influence of Habit in this respect is readily shewn by the changes which become developed from alterations in the hours of our daily meals and our nightly rest. It might be supposed that if this were the explanation, the periodical tendency would be slowly acquired, and would be developed in greatest force in later life. If, as seems fair, we may judge of the whole question from the temperature, it must be admitted that the periodical or daily range is greater, and is indeed better marked, in youth than

* Dr. C. F. Schneider, *Ein Beitrag zur Ermittelung der Sterblichkeits-Verhältnisse in Berlin nach den Tageszeiten.* *Virchow's Archiv.*, bd. 16. Berlin, 1859.

William West Watson, *Report upon the Vital, Social, and Economical Statistics of Glasgow* for 1865. Glasgow, 1866, Part I., p. 20.

† Dr. Murchison recognises this as one of the many dangers of Fever; and in his directions regarding food and stimulants, he says, "For it is usually in the early morning that the vital processes are at the lowest ebb."—*Treatise on Continued Fevers*, 2nd ed. London, 1873, p. 290.

in middle or later life. In the newly-born the daily range of temperature is certainly not yet established;* but the condition of such young infants differs so much from those of older children, that a diversity in this respect is but natural. It remains, however, for future inquiry to determine about what age the daily periodicity begins to manifest itself: and a study of the first eighteen or twenty months of life would be useful in this respect.

The question of Habit would be further elucidated by researches in the case of those whose occupations lead them to reverse, as it were, their days and nights; but I am not aware of any observations bearing on this point having been made.

It has been found that starvation, pushed the length of death, affected the degree, but did not alter the character of the daily range of temperature in the case of birds. It has also been found that a diet of water for a single day in the human subject left the excretion of urea to follow very much its usual periodical course: that quiescence from confinement to bed, that exclusion of the morning sunlight, and that absolute abstinence from food and drink for a limited time, left the daily curve of temperature but little affected; and, in like manner, that remaining awake for two or three nights did not prevent the pulse-rate from falling, as usual, at the midnight hours. But if, instead of these conditions being temporarily disturbed, certain combinations of them were systematically reversed in the daily life, the results might be very different. It is to be feared, however, that the habits of few night-workers are so completely and continuously reversed, with regard to day and night, as to afford a perfectly fair comparison in this respect. It may be stated, however, on the weighty authority of Professor Wunderlich, that the influence of Habit on the daily temperature is so potent, that even in the disturbances of febrile disease, a certain reversal of the usual daily range of the febrile temperature can sometimes be ascribed to the patients' occupation leading them to sleep by day and work by night.†

* v. Baerensprung gives the following average.—*Müller's Archiv.* Berlin, 1851, p. 162:—

	Morning.	Afternoon.	Evening.
Newly-born, . .	29°93 R.	30°24 R.	30°09 R.
Older Children, . .	29°90	30°46	29°70

† Dr. C. A. Wunderlich, *On the Temperature in Disease*: Translation. London, 1871. "Yet we meet with cases in which, without affecting the results, the daily fluctuations are misplaced (as regards the time of their occurrence), throughout a considerable period, or even through the whole course of a re-

Recurring to the question of Habit as affecting children, it may perhaps be questioned whether their exceeding susceptibility in this respect may not counterbalance the limited duration of the operation of Habit in their case. The power of Habit, like the tendency to Imitation, is well known to have a marvellous influence over the young. But in view of the increasing importance attributed in recent times to the transmission of Habits, and of functional and organic peculiarities from generation to generation,* it may be held for certain that the child does not come into the world with all its Habits to be acquired.

The orderly succession of Day and Night, inviting the human organism, in the most natural and varied manner, to alternations of energy and repose during countless generations, may well predispose the vital powers of the infant constitution to assume a daily periodical rhythm when once it begins to enter on a more separate existence than can be accorded to the utter dependence of the newly-born.

We may thus—through complex agencies and the subtle influence of Habit, whether hereditary or acquired—connect, as seems most meet, our daily period of depression with the darkness and repose of night, and the daily revival of our vital powers with the "glorious birth" of each new day.

DISCUSSION ON DR. FINLAYSON'S PAPER.

DR. MUIRHEAD, Cambuslang, who said he had had the pleasure of perusing Dr. Finlayson's MS. some days ago, offered the following remarks:—

Dr. Finlayson, in his concise and instructive paper, shews that the pulse, the temperature, and the solids of the urine all exhibit a

mittent fever (in typhoid fever or in influenza, for instance), the exacerbations occurring in the morning, and the remissions in the evening—individual peculiarities which at least sometimes result from the habits and mode of life of the patient—when, during health, they have slept by day and worked by night (as bakers do, for example)," pp. 235, 236.

* See Dr. Carpenter's *Physiology*, 7th ed. London, 1869, pp. 860–864, and footnotes; also, especially Dr. Carpenter's three articles in the *Contemporary Review*, "On the Hereditary Transmission of Psychical Habits," January, April, and May, 1873. The following sentence, quoted at p. 783, from Mr. Darwin, regarding *Winking*, indicates the tenor of the argument so far as concerns our present purpose:—"And, from what we know of inheritance, there is nothing improbable in the transmission of a habit to the offspring at an earlier age than that at which it was first acquired by the parents."

well-marked daily range of variation. It seems to me that the latter two of these phenomena must, to a considerable extent, be dependent on, and the result of, the first of them. At least, that just as the blood is sent faster through the system, so will occur a rise in the temperature, a more rapid using up of the materials consumed in vital processes, with a quicker conveyance of the effete products to the excretory apparatus in the kidneys. So that, for general purposes, we may reckon that in a healthy individual the rate of the temperature and the amount of the excreta, whether from the skin, the lungs, or the kidneys, will come and go with the rise and fall of the pulse-rate. For the pulse is an admirable index of the activities of the system which it pervades. Of course, I am here disregarding such temporarily disturbing agencies as external heat, the passage of unassimilated ingesta into the circulation, or absence of muscular locomotion.

Let me explain that I mean by all the activities, all mental and physical actings, as thinking, talking, gesticulating, moving the limbs and voluntary muscles (activities induced by contact with the world around us)—all internal motions which are mainly concerned in nutritive and depurating processes. All these actings consume the plasma and tissues of the body. These materials, containing a very large amount of motion in a latent form, are either, by being oxidised or otherwise chemically altered, made to part with a very considerable portion of the intermolecular motion, which passes into anything we move *mechanically;* or not so passing, shews as sensible heat, and gets out of the system either in a *radiating* manner with either units, or *convectively* with other more weighty excreta. Food furnishes the raw material from which real food is elaborated by the digesting and assimilating processes. This sifted and prepared organic matter replaces the organic matter used up by the various activities of the system. The using up of this material is the sole source of the motions of the living body, and of its heat (another form of motion). They can only be produced in the body from food and air introduced into it, and chemically altered by oxidation or otherwise. The excreta of the body, whether in the form of heat, mechanical motion, or other products, are all the results of these alterations.

Such being, I presume, a pretty fair statement of the case, then, I think, what we really want to find out is, simply, what is the cause of the daily variation of the pulse-rate?—the other two following merely, or mainly, as products, varying as it varies.

Well, then, disregarding for present purposes the disturbing

influence of irregularities in the incidencies of light and heat, of ingesta, which may be cold water, hot tea, alcoholic beverages, vegetable or animal foods, or even starvation or muscular inactivity for some time, let us inquire, what have been the general habits of our forefathers for, say, one hundred generations back, and what the average influences which these habits have had on our race during that period of time, so far as they affect the question at issue? I imagine that after a night-sleep men generally awoke between five and seven in the morning, or near one of these hours; that then mental and physical exercises were commenced, and continued more or less for sixteen hours or so per day—children requiring more sleep than adults; that these exercises necessitated the taking of food to supply the system with the materials spent through the performance of the functions of the living body; and that the propellers of the blood were, and are, the active agents in carrying the materials poured into it to the different organs of the body—yea, even to those organs which prepare and pour the new materials into their own circulating contents. Thus engaged, these propellers partake of the general animation which comes to pervade the system with the awakening of consciousness and voluntary activity every morning—consciousness being the reflex actions excited in the brain by intimations sent in through the sensal nerves from things around us, with remembrances of these and other operations of the mind.

Well, the awakening of consciousness, and the renewed activity consequent thereon, are shewn in the increasing pulse-rate—helped, of course, by food supplied to replace departing energies—till towards evening the jaded system and the propelling agencies, as part of that system, no longer respond to the usual stimuli with the same degree of freshness, or accumulated energy, which, together with the absence of the action of external stimuli when sleep supervenes at night, introduce a state of things where the reacting organic activities are at their lowest, and are evidenced to us to be so by the minimum rate of pulsations. Whether reorganisation proceeds faster during sleeping or waking hours, or equally, I cannot say, but generally during the day the expenditure of energy is greater than its regeneration; while during sound sleep, its regeneration is greater than its expenditure. So that in the morning man starts re-invigorated and fresh—that is, with a store of accumulated vital materials similar to those used up the preceding day, usually getting a fillip from each meal; for each, independently of its usually containing some little diffusible stimulant, as heat or alcohol, operates also by exciting the stomach to renewed action, and so

reacts on the circulating agencies, as all excitants do, whether mental or physical.

Such, then, I take to have been the general daily routine gone through by the vital functions or organs of our race for numberless generations; and we see still that the energies of the tired-out system, re-invigorated by the quiet action of the assimilating organs during undisturbed sleep, respond freshly to stimuli during the first half of the usual waking hours. Then they get to flag more and more, as night draws on, although, like those of a jaded horse, they may be occasionally supplemented by diffusible stimuli, or stung into spasmodic action by whip and spur, only to exhaust the system to a still greater degree. But leaving aside these accidents as of no great moment in the general average of routine, we see that when the energies of the system are tired out, and the excitements from external agencies are nearly wholly absent in sound sleep at night, the pulse is at its minimum rate; but not entirely quiescent, for regenerating agencies are still at work, and vital energy is being formed, and accumulated, more and more towards morning, ready to respond to stimuli so soon as the habits of the race, modified by the habits of the individual, awaken the latter to renewed consciousness and muscular activity.

Such, then, I say, I take to be the cycle of variations, the daily rhythm, as it were, which we inherit from a long line of ancestors, however disturbed by occasionally varying contingencies. Dr. Finlayson has very distinctly alluded to this view in his concluding remarks, but he has not brought it quite so prominently forward as I have endeavoured to do, and which I think its importance demands, especially in a Society calling itself Philosophical. I may add, that the daily periodicity of the pulse-rate and its associated phenomena indicate very plainly that man is a diurnal, and not a nocturnal animal.* That is to say, his activities are in general largely developed during the day-time, leading more or less to exhaustion towards evening, when sleep supervenes; and that then the organism, whose vital energies have been largely drawn upon, is quietly permitted to lay up accumulated stores for the coming day; the pulse-rate (in a healthy individual), as Dr. F. has shewn,

* It occurs to me, that as the hour varies with the longitude, if we were to examine the pulses of persons coming to Britain from the far East and from the far West, or ask competent authorities in Asia, America, and Australia to note those of emigrants from Europe, the effects of the change of semi-diurnal habits might be more easily and much more distinctly traced than in bakers and miners in this country. The pulses of nocturnal animals might also be investigated.

very generally indicating the sum of the activities at work in the system, and so of the excreta given out in the form of work, heat, and other more ponderable matters.

One remark in reference to the rise in the curve of the death-rate from midnight to 5 A.M. In addition to the physiological causes enumerated by Dr. F., I venture to suggest that, after a long and exhaustive illness, when the lamp of life is feebly fluttering, and all but expiring, it may depend on the proper administration of cordials whether or not life will be prolonged. Human nature is sometimes frail, and, in addition, is sometimes faulty. During the watches of the night, from the first or from both causes, stimulants may not be administered, which might have kept the fluttering flame alive, at least until after five o'clock. We see that the death-rate increases from midnight till that hour, a period when probably, in most cases of the kind alluded to, stimulants will be administered.

DR. MORTON—I may state that I have a recollection of reading on this matter, some thirty years ago, with results stated very much like those that we have now heard. But I do not think those we have now listened to are the less valuable on that account. They point out researches made by men in more modern times, and perhaps with better appliances, which indicate the same results as were got then.

There is only one thing I would like to mention, or rather to recommend, to those who pursue this study, and that is, a comparison of temperatures in the air. There can be no doubt there is a great deal to be said in regard to our mode of living. But I think we might follow out the researches necessary, by trying the effect of placing ourselves in various circumstanees, say, by going down a coal-pit, and making observations there. My object in making that observation is, to point out that we would there, at least, get rid of the effects of light to a great extent, and to that is attributed a great deal of the effect. So much have some medical philosophers been taken with this idea of the effect of light, that they have actually founded a system of treatment on it. They carried this so far as to expose weak, scrofulous children to the direct rays of the sun, in a nude state, for a lengthened period of time, so as to produce an effect on the system. There is another direction in which researches might be carried, and that is, as they are still making efforts to reach the North Pole, we might get observations made there for a period of two or three months when

the sun is not seen. I don't mean to say there are no effects from the sun there, but its effects are reduced to a minimum.

Dr. Eben. Watson said—The subject has been brought before us very well, and in a very interesting manner, by Dr. Finlayson. It is a very difficult subject, let me say in starting. It is not a subject that can be jumped into, or jumped over, but it is one requiring very careful study. I must say I feel a great difficulty myself in speaking upon it at all to-night. I can hardly presume to follow Dr. Finlayson in his paper, and in the many points he has started, which, I am not ashamed to say, are to myself in some degree new. I don't think the observations of Dr. John Davy are such as at all meet the points raised in the paper read to us to-night; and I would also make it as another remark—that it is well known, and has long been known—that external temperature has very little to do with the temperature of the body. I would also say, that I quite agree with Dr. Finlayson, that the pulse-rate and the degree of temperature must always be somewhat similar. And I think he is also right in taking the secretion of urine as another measure of vital changes. He has gone somewhat beyond others who have preceded him in these investigations, by pointing out so distinctly that there is a diurnal range in all these changes. Dr. Finlayson brought us first to the consideration of this question as a matter of fact. He quite refrained from theorising on the subject. Now, is it a fact, or is it not? I think we must agree that there is a diurnal rise and fall in the performance of some of the functions in the human body. We come next to the very interesting inquiry of the cause. Dr. Finlayson did not inquire into the cause formally; but this is a very important point, and one to which he drew attention in the latter part of his paper, though very shortly, and not quite so systematically as in regard to the fact. I think, in discussing this, we must go into the theory of the cause of animal heat, especially in the human body, and we shall then find that it is closely connected with the minute changes in all the tissues in which their nutrition consists, and that it does not exactly depend so much upon the greater operations of the economy, such as digestion or excretions. The minute changes to which I refer are those which take place in the tissues themselves, and which consist essentially of the oxidation of their used-up carbon. Thus, carbonic acid is formed, which is conveyed in the blood to be exhaled at the lungs along with the other forms of car-

bon, such as fat and sugar, which are also carried by the blood, and are oxidised in the lungs themselves. These two sources of carbonic acid, or, in other words, these two sources of fuel for combustion in the body, are, in my opinion, the chief, but perhaps not the only causes of its animal heat. Now, it is very strange that there should be a diurnal variation in the amount of carbon sent to the lungs for combustion and exhalation; but so it would appear there is, from the paper just read. I shall not dogmatise upon the possible cause of this, but I would suggest that it may be due to the vitality of the tissues which, in ordinary phraseology, can be worn out as well as that of our muscular system, of which we are now sensible. Hence it may be that, after performing their function of nutrition for a certain time, they cease to do so, at least with the same vigour and to the same extent; and as all the functions of the body are mutually dependent, so our waking time being that in which we take food and exercise, is necessarily that likewise in which the formation of carbonic acid, and therefore the temperature, is greatest, while, for obvious reasons, both are diminished during rest. The only want which I felt in Dr. Finlayson's paper was, that he did not sufficiently refer to respiration. Probably the reason of this was, that he did not quite formally enter upon the cause of animal heat. I think we are indebted to Dr. Finlayson for having called the attention of the Society to this subject; and I make these remarks, more to indicate my sense of the importance of the paper, than by way of adding to the communication which has been made to us. I would simply conclude by expressing my thanks to Dr. Finlayson, and my appreciation of his paper.

MR. J. J. COLEMAN, F.C.S.—Although the question is complicated when the body is in motion, when the body is at rest its temperature must be due to the chemical changes occurring in the system. The rapidity of these changes, and consequently the heat produced, corresponds with the pulse-rate, as shewn in the diagrams. It is well acknowledged by physiologists that we do not understand the real nature of vital forces, and that they have an important bearing upon the chemical point of the question. It appears to me that the nervous energy which causes the increase of the activity of the circulation (as denoted by the pulse) is gradually acquired during the repose of the system in sleep. During the daytime, nervous force is expended in emotional and other forms of nervous excitement. In many cases of emotional excitement, it is extremely

difficult sometimes even to take or digest food, and therefore the nervous system has an important effect upon the chemical changes which are occurring in the body, as it has been observed that the pulse-rate is an indication of the variations in temperature occurring in the body.

Dr. Finlayson—In regard to the peculiarities connected with the number of deaths occurring between eleven and twelve at night, as compared with those occurring between twelve and one in the morning, it might interest the members to know that in one of the large institutions in this city he had found, on tabulating the deaths, a similar perturbation, but exactly reversed as regards the two hours in question—thus confirming the guess he had made as to the accidental cause of this difference. He should mention that this was ascertained after the paper had been written.

II.—*On the Analysis and Purification of Water.* By Gustav Bischof, Professor of Technical Chemistry at the Andersonian University, Glasgow.

[Read before Chemical Section, on 8th December, 1873.]

Considering the conflicting evidence we have at present regarding Frankland and Armstrong's method of water analysis,* it appeared to me desirable to test this method in several ways, in some of which it has not yet, as far as I am aware, been tested.

I divided the method into three stages—1*st.* The measurement of the gases; 2*nd.* The combustion of the residue; 3*rd.* The evaporation of the water. The accuracy of each of these stages was tested separately, in order to ascertain to which stage any inaccuracies might be due.

1. Pure carbon, dioxide, and nitrogen were mixed at about the same ratio at which they occur in water. The mixture of gases

* For a complete description of the apparatus employed, see T. E. Thorpe, *Quantitative Chemical Analysis*, p. 305; or F. Sutton, *Volumetric Analysis*, p. 264.

was determined repeatedly, all the reagents being introduced into the laboratory vessel which are required for an analysis. Such quantities of carbon and nitrogen as occur in pure water could readily be measured to within 0·69 per cent. of the actual quantity present. There was only one unaccountable exception to this rule amongst a large number of measurements. When measuring 0·76 C. C. of the mixture, I found 93·58 per cent. of carbon and 6·42 of nitrogen, instead of 89·02 carbon and 10·98 nitrogen. My first supposition, that this might be due to an absorption of the nitrogen, perhaps by an unusually large proportion of the reagents added, had to be abandoned; for, after leaving 0·08 C. C. of nitrogen in contact over night with a large excess of the reagents, its volume remained perfectly unaltered. I therefore feel strongly inclined to attribute the one incorrect result to an error in reading off the divisions of the measuring tubes.

However, I found that it is of consequence in measuring *very* small quantities of gas, whether the solution of the reagents be allowed to pass more or less into the horizontal thermometer tube connecting the laboratory vessel with the measuring tubes, and that it makes a considerable difference if the gas be passed in one instance to the right, and in another to the left side of the first stop-cock, especially if the bore of the thermometer tube does not remain equal throughout, but bulges out, which is sometimes the case in apparatus constructed without due care. As it is difficult to stop the inflow always at exactly the same place, a few graduations on the horizontal tube might allow for a correction in the case of very small volumes of gases.

In measuring gases resulting from combustions, carbon monoxide is, according to my experience, more frequently present than might be expected from Sutton's description, and I therefore always test for this gas.

The gas resulting from the combustion of the residue of evaporation of an impure water was next divided into several portions, which were unexceptionally determined with the greatest accuracy, as was evident from the relative proportion of carbon and nitrogen obtained.

A different and, in my opinion, more convenient pipette than that used by Dr. Frankland has been introduced by Dr. William Ramsay, one of my assistants, for transferring the liquid reagents into the laboratory vessel. This consists of a glass tube of say 5 mm. internal diameter, drawn out into two capillary tubes 30 to 40 mm. distant from each other, as will be understood

from fig. 1. One of the capillary tubes is bent round in the shape of letter U. If a liquid be sucked up through the straight capillary tube into the enlarged tube, and then the bent tube introduced into the inner side of the laboratory vessel, but above the level of the mercury in the trough, the liquid passes into the laboratory vessel. The smallest quantities may thus be passed in, as the inflow is at once stopped if the lower end of the pipette be depressed below the level of the mercury in the trough. The straight end of the pipette is conveniently passed through a cork, when it may be kept in the bottle containing the reagent.

Fig. 1. ¼ Nat. Size.

2. I make the copper spirals, which are used in the combustion tube, by winding evenly fine copper wire round a central wire, and I prefer having this, as also the copper oxide, tight in the combustion tube. As the latter might choke, I always let a drop of water fall on to the sealed end of the combustion tube after the combustion has been finished and the test tube containing the gas removed. The falling of the mercury in the delivery tube of the air-pump at once indicates if the combustion tube was not choked. However fine and tight the copper oxide, a choking takes place very rarely.

The experiments regarding the combustion of water residues were hitherto confined to dividing residues obtained by the evaporation of impure waters into several portions, which were separately burnt, the resulting gases being also separately measured. The results thus obtained were very close, shewing that a remarkable conformity is obtainable by the combustion of like samples.

3. Like quantities of Loch Katrine water were evaporated under the same and under different conditions as to temperature, but always under the glass shades. The residues were burnt and measured separately. I think I may conclude, from the results thus obtained, that the temperature and the time allowed for evaporating the water is of consequence, inasmuch as a rather larger proportion of organic nitrogen is obtained, if the evaporation be finished in a comparatively short time—say, a litre in eighteen to twenty hours—than if, at a lower temperature, five or six days be allowed. This might, perhaps, be due to a fermentation setting in and altering the nitrogenous organic matter. The sulphurous acid, which acts as an antiseptic, is, in Dr. Frankland's and also in my laboratory, only added to the contents of the flask in which the sample is boiled and kept, but not to the contents of the evaporating dish. Hence, if the contents of the dish be repeatedly exposed

for a long time to a temperature of say 50° to 60° C., the sulphurous acid may be driven off, and fermentation set in during part of that time.

However this may be, it appeared to me desirable to accelerate the evaporation as much as possible, and to render the gradual addition of new portions of the sample to be evaporated self-acting. I had further in view that the evaporation should be finished more uniformly as to time than hitherto attainable in my laboratory, and that the whole arrangement should be more easily accessible to all chemists than the arrangement which is at present in use at the Rivers' Commission Laboratory in London. To this end I place on to the copper dish, *a a* (fig. 2), in which the glass dish, *b b*, is heated, a copper ring, *c c*, 80 MM. high, provided on its top with a slightly inclined rim of the same diameter as that of the copper dish, so that the glass shade, *d*, may rest on either. The self-

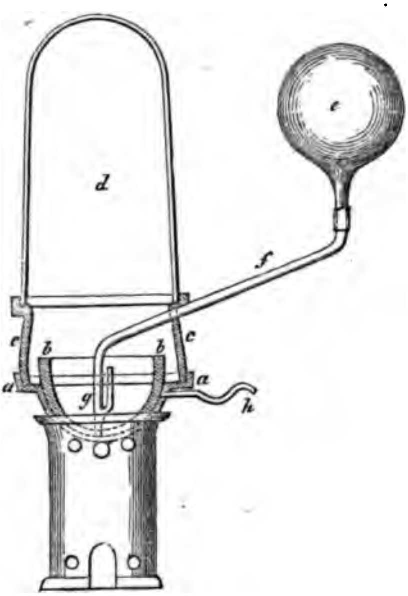


Fig. 2.—¼ Nat. Size.

filtering apparatus consists of a flask, *e*, with rounded bottom, of rather more than one litre capacity, the neck of which is ground so accurately into the enlarged end of a glass tube, *f*, of about 8 MM. internal diameter, as to be water-tight without the use of grease. The tube close to the enlarged end is bent at an angle of about 120°. The other end of the tube, which is formed by one of the usual self-filtering arrangements, *g*, is again bent so as to be

parallel with the enlarged end of the tube. The water and sulphurous acid having been introduced into the flask, the tube is attached, the apparatus inverted and introduced through a slit in the top of the copper ring into the glass dish, without, however, touching its bottom. The slit should be so deep that the glass shade does not quite touch the glass tube.

I employ glass dishes of 150 MM. diameter. When the litre flask is nearly empty, the copper ring and self-filtering apparatus are taken off, after allowing the last portions of water to run into the glass dish, and the glass cover is placed directly on the copper dish. The copper dish, which rests on a Griffin's gas furnace, is heated by means of a Bunsen burner, the temperature being regulated by the Bunsen-Kemp gas regulator, as modified by me (Fresenius, *Zeitschrift*, x., p. 442). The copper dish is half-filled with pure distilled water, and the temperature so regulated that the water is kept in a state of very gentle ebullition, the excess of the condensed water running off through a syphon-tube, *h*, attached to the copper dish. The evaporation of a litre of water may by these means easily be finished in sixteen to eighteen hours.

The next questions to which my attention will be directed are—the action of any free acid formed during the evaporation on organic matter, the elimination of nitrates and nitrites during the evaporation, and whether the results are reliable when determining the minute quantities of organic impurities which occur in comparatively pure waters. Other questions will probably suggest themselves in the course of these experiments. As water analysis is such a very important branch of our laboratory work, I hope I shall be permitted to lay the results arrived at before the Society at some future meeting.

In conclusion, one of the spongy iron water filters, referred to at page 370 of the *Proceedings*, 1872–73, was exhibited and explained. One of these filters has now been in constant action in London for three and a half months, filtering the water supplied by the Chelsea Water Company. The analytical results shew that the purifying action of the spongy iron has not in the least been decreased during that time, and the hardness of the water is still reduced to nearly one-half. This experiment is being continued; but it may be pointed out that animal charcoal, probably the best filtering material hitherto known, frequently shews signs of decomposition after three months' use, and then contaminates the water. The purifying action of spongy iron appears, therefore, to be also, in this respect, superior to that of animal charcoal.

III.—*On Water Supply.* By STEVENSON MACADAM, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry, Edinburgh.

[Read before the Society, on 21st January, 1874.]

THE primary uses of water are for drinking, cooking, and washing. So far as drinking and cooking—dietetic—purposes are concerned, the quantity of water absolutely required is comparatively small, probably a gallon a head might suffice, and the amount necessary for personal ablutions might be reduced to another gallon, being for primary purposes, in primitive fashion, two gallons a head per day. But the cleansing of clothes and of furniture, as well as the floors, walls, and stairs of houses, necessitates a much larger supply. Even the smallest house, with its modicum of furniture, and the scantiest of clothing, makes large demands upon water. Still more so, when the tendency of the present age is for all classes to live better than their forefathers—to have more roomy and airy houses, and to use more underclothing, and have more change of such, each necessitating more consumpt of water for their thorough and efficient cleansing. Even personal ablutions, as they ought to be carried out, by the periodic cleansing of the whole body in baths, where such are available, and in tubs, where baths are too great luxuries, demand an increasing supply of water. And then our plan of drainage and sewerage, coupled with the water-closet system, has formidable and earnest claims upon quantity of water for the removal of impurities, not only from our houses into the sewers, but even more so from the sewers themselves.

It may be a question whether the water system for the removal of night-soil and other impurities is a correct one, as now carried out. I have grave doubts about it, unless quantity of water can be ensured at all times. The condition of the sewers in towns—built piecemeal as they are—is certainly not the best. Accumulations of fœtid matter are common in these underground tunnels, evolving pernicious gases, which permeate our house-drains and contaminate the air of our rooms. Means ought to be at hand for the weekly flushing of sewers, so as to remove depositing, putrefying matter, and thus ensure mechanical cleansing. But equally important as a sister aid is the constant small run of water through sewers, which leads to

chemical cleansing; for the water contains gases in solution, of which oxygen is one, and while flowing over deposited matter, or even over the foul bottom of the sewer, the dissolved oxygen burns up or oxidises the noxious gases evolved, and thus removes these from our drains and sewers. I have little faith in the separate system of drains. At present there is a chance of flushing by rainfall, and the consequent removal of foul matters; but by the separate system of conduits, such periodic flushing will be practically lost. Still less have I faith in the water-closet system introduced into small houses. It is an element of danger at any time, and where little care is taken, becomes highly dangerous. Much better to retain and amplify the present privy system, or adopt the Liverpool method of tank closets in the yards attached to each tenement, or the more troublesome, but certainly less dangerous system of the earth-closet for each land of houses.

The rapid progress of the arts and manufactures likewise demands an increasing supply of water. In Glasgow the question of the quantity of water required per head has been practically solved by the use of fully fifty gallons per head per day; and in Edinburgh, the better houses are found to consume fully sixty gallons per head per day.

1. *Quality of Water.*

All natural waters contain more or less saline ingredients, and all possess a greater or less amount of organic matter, besides gases, in solution. Neither the saline nor the organic matters are necessarily impurities. They may be the natural constituents of wholesome waters. The saline matters are principally carbonate of lime (chalk), sulphate of lime (stucco), and chloride of sodium (common salt), with a small proportion of magnesium compounds. The organic matter is of vegetable origin, and is not putrescent. Certain saline matters may, however, render waters unsuitable for primary uses, as hydrosulphuric acid (sulphuretted hydrogen), which is present in sulphureous waters, and the carbonate and sulphate of iron, which are found in chalybeate waters. Even excessive proportions of the ordinary constituents communicate undesirable properties upon water, as much carbonate and sulphate of lime constitute unduly hard or calcareous waters, and much chloride of calcium and chloride of sodium yield saline purging springs. As a general rule, the larger the proportion of saline matter, the greater the degree of hardness. For cleansing purposes there is a decided

disadvantage in hard water. It necessitates more or less waste of soda and soap. Independently of that, for personal ablutions soft water is much more agreeable and effective. For cooking purposes a comparatively soft water is advantageous. It is more effective in extracting the nutrient value in infusions and extracts, such as tea, coffee, soups, etc. Hard waters are positively a hindrance in cooking many articles, as insoluble compounds are formed with the lime. Besides, hard waters lead to the incrustation of vessels, which necessitates extra firing, and a certain risk in the filling up of pipes, and the consequent explosion of boilers, etc. For drinking purposes, it is of little moment whether the water is hard or soft, provided it is palatable, which more depends on the gases dissolved in the water than on the saline matters in solution. For instance, hard water, when boiled or heated, and then allowed to cool, is very mawkish to taste; whilst distilled water, when the distil-ærator is employed, is in all respects decidedly palatable.

The large proportion of lime in the ordinary articles of food renders it unnecessary that lime should be present in the water supply; and, moreover, the lime in water is in the form either of carbonate or sulphate of lime, which is not the principal state in which it is required for the wants of the animal frame, which makes great demands on the phosphate of lime for the building up and sustenance of the bony skeleton. For town supply, a water containing not more than 5° of hardness is of first-class quality for all domestic purposes. When the degree of hardness rangês between 5° and 10° the water is of second-class quality; and when from 10° to 20° of hardness, the water is of third-class quality.

The organic matter present in waters may be of various kinds. In ordinary, natural, healthy, or wholesome water, the organic matter is of vegetable extraction. It may be of a peaty nature, when a yellow shade of colour is observable, or of a non-peaty character, when the colour is not affected. The average quantity of organic matter in water is about two-thirds of a grain in the imperial gallon. The colour is very deceptive in this case, for the organic constituents are often present in as large quantity in colourless as in coloured waters. The presence of lime hinders the observance of the colour — due, apparently, to the formation of a colourless compound. A water containing much peaty matter, when treated with a very small amount of lime, and then filtered, becomes quite colourless. The same result takes place more slowly when carbonate of lime, in the form of shells or pieces of lime rock, are present in the filtering bed. A mixture of the

peaty water with a hard water gives rise to a similar decoloration of the mixed liquid.

We must distinctly draw the line between the above or non-putrescent organic matter and putrescent organic matter, either of vegetable or animal origin. Marshy waters become impregnated with vegetable matter, which is liable to putrefaction, and hence marshy waters do not belong to the same class as those tinged with peat. There is a decided difference in the nature and proportion of the gases. Animal impregnations, derived either from sewage or from highly manured fields, give rise to the most dreaded form of contamination, which may, when the entrance of the impurity is direct, be visible to the naked eye; but when the organic matter has percolated through the soil, it may be in part oxidised into nitrates, and the water be obtained perfectly clear and sparkling, as well as cool and refreshing, and yet be positively unwholesome and deadly when partaken of for dietetic purposes. The quantity of organic matter dissolved in the waters of the present Edinburgh and Glasgow supply is close upon two-thirds of a grain in the imperial gallon, and there is practically no difference in the amount furnished by each water. This organic matter is entirely non-putrescent. Where the peaty matter is much greater in quantity, the organic matter may be as much as 1½ grains to 2¼ grains in the imperial gallon. In waters which are contaminated by the products of animal matters derivable from sewage or from highly manured fields, the amount of organic matter ranges from 1 to 10 or more grains in the imperial gallon.

The gases dissolved in waters form one of the best guides as to the quality of the waters. These gases are mainly carbonic acid, oxygen, and nitrogen. The proportion of carbonic acid varies according to hardness when such is derivable from carbonates, whilst the relative amounts of oxygen and nitrogen should be very nearly as 1 of oxygen to 2 of nitrogen. When the water is of a wholesome nature, and the organic matter is non-putrescent, then such is the ratio of these gases; but where there is putrescence, the oxygen decreases to 1 to 3 or less, which is indicative of positively unwholesome properties being present in the water. For instance, in the course of the inquiry into the condition of the Water of Leith, which at the time formed one of the main sewage drains of Edinburgh and Leith, I had occasion to make many testings, which led to these results; and the subsequent analyses of many hundreds of waters received from all quarters has confirmed these conclusions. The gases dissolved in spring, river,

and loch waters, are as follows, taking the average results of many experiments made on each set of waters:—

	Spring Water.	River Water.	Loch Water.
Carbonic Acid, ...	10	5	4½
Oxygen, ...	29	30	30¼
Nitrogen, ...	61	65	65¼

In neither water, when kept for months in closed bottles, was there any practical difference in the quality of the gases or in any other property. The organic matter was, therefore, in all these waters of a non-putrescent and wholesome nature. At the same time, contact with the air and sunlight has a material influence on the organic matter, which is thereby oxidised, and tends to lessen in quantity, so that the water becomes more and more colourless in course of time.

2. *Vegetable and Animal Life in Water.*

All waters, when exposed to the air, become more or less impregnated with organisms. Even spring water which has never seen the light of day till it is run into our house-cisterns, very soon acquires organisms, especially in the warmer months of the year, and in the warmer situations in households. In wholesome natural waters impounded in natural or artificial reservoirs or ponds, the vegetable growth consists mainly of fresh-water algæ, which adhere to and grow on stones in the quiescent parts, where there is little current, and where the stones do not roll over each other, but are stationary. Every highland and lowland loch is an illustration of this. Go to Loch Katrine or Loch Lomond, Loch Lubnaig or Loch Earn, Lochs Venacher or Achray, Lochs Menteith, Chon, or Ard, or any other loch or impounded water, and at all the quiescent parts you have the same vegetable growth—the same fresh-water algæ. Wherever there is a sheltered spot, and where the wind and the waves do not roll stones over each other, there you have vegetable growth or algæ. The vegetable growth is common to all the stones on the shores of natural and artificial lochs and reservoirs, and to the more quiet running parts of streams, and is more evidence of purity in water than of impurity.

The animal life visible in fresh waters consists mainly of minute organisms, about the size of a pin-head, and which are minute crustaceans, principally *Daphnia pulex* and *Cyclops quadricornis.* Of course, at the sides of all lochs and reservoirs you can pick up the larvæ of insects, water scorpions, and other

animal forms which live on shore, and which are equally found in every impounded water and in every running stream. The so-called water-fleas, however, the *Daphnia pulex* and the *Cyclops quadricornis*, are the denizens of the water, and are distributed throughout the lochs, and are also found in house-cisterns. The cyclops is the more common, and seems to appear earlier in the season. In June they are abundant in every fresh-water pond and loch. As the month progresses, the daphnia becomes abundant. In Loch Lomond you will everywhere find the cyclops, not only at the side, but all up the middle of the loch: wherever a bottle is put down, the water which is drawn up always brings up some fleas. At Loch Katrine, all along the shores, including the region immediately surrounding the mouth of the tunnel leading to Glasgow, the fleas are present in the water, as well as at the piers, and throughout the whole length of the loch. You cannot lift a bottle of the water without finding the water-flea. In August, more vegetable and animal life are to be found everywhere in all the lochs and reservoirs.

The water-fleas are extremely delicate organisms. A very little alcohol added to the water kills them; and when the water is heated to the temperature of 100° Fahr., they die at once. Any decrease in the amount of the oxygen dissolved in the water below the wholesome quantity quickly causes their death. Thus, when water containing the fleas is bottled up for a night, the majority, if not all, of the fleas will be found dead in the morning. Care must be taken to leave the bottles open, so as to ensure the continual æration of the water, and thus enable the fleas to have the most wholesome of air in solution in the water. Fleas, therefore, are evidence of the purity of waters. They are never found in contaminated waters. Not a single flea was observed in the whole course of the experimental observations on the Water of Leith when containing the sewage of Edinburgh. Any putrescent material introduced into the water will influence the quantity of gases in solution, and the fleas die by foul air. These remarks apply equally to hard and soft waters. In running streams the fleas are found in all the quiet corners where the current is reduced to a minimum. Filtration through sand and gravel removes the greater number of the fleas, but not all.

In sewage-impregnated waters, such as streams and rivers into which town drainage runs, the vegetable and animal life are of a distinct and especial character. The stones in the bed of the stream are covered with offensive organic growths,

which are characteristic of waters conveying sewage, and capable of decomposing and evolving unwholesome gases. Indeed, not only are the stones covered with such vegetable growths, but everything in the bed of the river, such as arrested portions of trees, become thickly coated. These growths principally consist of those low forms of vegetable life which are regarded by some naturalists as fungi, and by others as algæ, and they are accompanied by masses of animals belonging to the family of Vorticellidæ, including the genera *Vorticella*, *Carchesium*, *Zoothamnium*, and *Epistylis*. These organic matters are being constantly detached from the stones, &c., on which they grow, and the torn-off fragments float down the stream and form part of some deposit in a rocky pool. During the spring months the growths are apparently stronger, and form longer streamers than during the summer months. The temperature of the latter is higher, and facilitates changes, such as the disintegration of the mass. These growths appear to be the last stage of organic life which will inhabit foul water; but in places where, in the spring, many patches of the growth were observed, in summer hardly any was to be noticed. This disappearance, in part at least, of the growth is to be attributed to the more foul state of the water in summer, which leads in some places to such a rapid putrefaction as even to arrest the development of this comparatively simple form of organic life.

The animal life which is specially visible to the naked eye in sewage-impregnated streams are worms, which are abundant in many places, and are regarded as the last remnant of animal life which will exist in water contaminated by sewage. These minute red worms are a kind of Nais, belonging to the family Naidina, and are named *Tubifex rivulorum*. They are found in greater abundance during spring than in summer, apparently from the more active putrescence of the sedimentary matter leading in the summer to the disengagement of a more full supply of noxious gases, which even these minute worms cannot survive. Abundance of animalculæ, including the *Paramœcia*, were found in the Water of Leith at all seasons of the year.

3. *Action of Water upon Lead.*

The common notion that soft waters act more upon lead than hard waters is erroneous. During a very lengthened experience as an analyst, I have found many more hard waters which acted upon lead than soft waters which did so. A natural water, taken from a stream, lake, or spring, and containing the proper kinds of in-

gredients—however soft—has no deleterious action upon lead; but when impurities are present in either hard or soft waters, they have a more or less powerful action upon lead. Then the impregnation of either soft or hard water with sewage products or drainings of highly manured land, confers upon the water the property of dissolving lead, which is mainly due to the action of the nitrate of lime dissolved in the water. A similar result is traceable to marshy water, which contains putrescent material; but no such action upon lead occurs with waters which have a peaty tinge. The late Professor Miller, of King's College, London, even said that the peaty matter was a preservative against the water acting upon the lead; but I scarcely think it necessary to consider that such is the case. Hard waters are more likely to be contaminated with impurities, because they generally rise in lowland districts, where there is a considerable population, which directly or indirectly sends sewage into the streams, and where the arable land is heavily manured. Soft waters, on the other hand, can scarcely be polluted at all, for they generally rise in hilly districts, where there is a scattered population and scanty cultivation, so that neither sewage nor the drainings of highly-manured fields can contaminate them.

The proper mode of testing the action of water upon lead is to proceed to bring the lead and water in contact with each other as they would be in ordinary use. The placing of pieces of sheet-lead with fresh-cut edges, and often with scraped surfaces, in the water contained in the bottle, is not to be commended, as the results give an exaggerated notion of the power of the water to act upon lead. Indeed, there is no natural water which may not in this way be shewn to act so powerfully on lead as to be hurtful and poisonous. The proper method of testing the action is to bring the water in contact with the lead having its natural skin or surface, which is probably a thin film of oxycarbonate of lead. A short length of lead pipe, an inch in diameter, with one end beaten close, or a lead cistern soldered in the ordinary way, may be employed in the experiments. The pipe or cistern is rinsed out with the water to be examined, and the tube or cistern is then filled up, and the water allowed to stand in it for at least 24 hours. In my late experiments I have supplemented those smaller trials with a cistern to which there is attached 20 feet of lead pipe and a brass stopcock, the whole being soldered and fitted together in the same manner as an ordinary house-cistern with pipe and cock is constructed.

Working, therefore, with the short length of pipe, the small cistern, and the house-cistern and pipe, I find that when the lead is fresh and new, the action of good wholesome water during the first 24 hours is to the extent of $\frac{1}{100}$ of a grain of lead in a gallon of water, which decreases in a week to $\frac{1}{400}$ of a grain, even when allowed to stand for three days; and thereafter the action does not exceed the $\frac{1}{500}$ of a grain, even when the water remains in the cistern. Where the water is run in and out, as takes place in daily use in households, the proportion of lead in solution becomes infinitesimal, and cannot be recognised even by chemical tests. Even at the first, the action is far within the limits of safety; and certainly, when a few days are past, the water ceases practically to have any solvent power over the lead.

A word of caution requires, however, to be given in regard to dirty cisterns, especially when lime falls into them, as a sediment is often found in cisterns which contains much sand and clay accompanied by lime, and much carbonate of lead in fine division. Where such is the case, the rapid influx of the water may stir up this sediment, and cause part of the carbonate of lead to be mechanically diffused through the water, which may thus exert deleterious properties. All cisterns should be cleaned out once a month with a soft brush, so as to avoid the contamination alluded to here.

4. *Nature of Gathering Ground.*

That water for town supply should not be collected in the neighbourhood of populous places, either from the surface or from wells, will be admitted by all. Professional acquaintance with the water supply of many towns and villages has led me to the conclusion that at least three-fourths of all the well-waters in populous places are contaminated with sewage, and are unwholesome. That water should be collected from cultivated districts is scarcely less to be deprecated. The fields are often highly manured, sometimes with police manure, and the drainings from such are more or less polluted with noxious ingredients. Even districts which are likely to be chosen for breaking up by farmers—comparatively flat land or agricultural areas—should not be fixed upon for the water supply of large towns. Numerous instances can be adduced of water of good quality at one time, becoming thus contaminated by the breaking in and manuring of land, leading to unwholesomeness in the water, as well as the power to act more or less upon lead. Districts having hard waters are more likely to be influenced by the

progress of agriculture, because they are generally more flat, whilst soft-water districts, being more hilly as a rule, are less capable of being turned to arable purposes, and hence remain strictly pastoral.

The drawback to soft-water districts is the presence of more or less peat, which communicates a greater or less tinge of colour to the water; but surely the mere appearance of a water is not to be sacrificed to unwholesomeness. The majority of highland and lowland lochs, the districts draining into such, as also the available collecting grounds for artificial reservoirs, must necessarily be in localities where there is some peat; and such is certainly as abundant in the highlands as in the lowlands. It is equally sure that highland lochs as well as lowland lochs contain water which is tinged with peat. A slight impregnation of the water with peat should not be considered objectionable, as it is not unwholesome. No pernicious effects have ever been traced to such. Difficulties have arisen from mixing up marshy water, peaty water, and sewage-impregnated water together. Many towns are supplied with the so-called peaty water, including Glasgow, Aberdeen, and Inverness, and there is absolutely no proof whatever of any noxious quality being derived therefrom.

In lifting samples of water for chemical analysis, care should be taken that the water is collected as it naturally flows in the stream or loch, and that the banks or bottom be not disturbed. Where the water is to be taken from the side, it is better to lift it in a large spoon lined with porcelain and attached to a wooden pole, so that the operator may stand firmly on the bank without disturbing the stones or earth on the immediate brink, and be able to stretch out the instrument some feet into the stream or loch. Where no such lifter is used, and the collector stands on earth or stones immediately alongside, or in the water course, and dips down the bottle, there is almost certain to be disturbance of the bottom, and more or less sedimentary matter passing into the bottle. Where the water is to be collected at depths not exceeding six feet, I employ a galvanised iron cylinder, fitted up with tubes and stopcocks, which can be opened and closed when the cylinder is lowered to the required depth. Where it is desirable to take the water from greater depths—say 20, 50, or 100 feet—I use a galvanised cylinder fitted up with a valvular arrangement, which remains open when the apparatus is being lowered in the water, and closes at once on the descent being arrested at any point. In order to admit of the apparatus being lowered perpendicularly with sufficient rapidity, to ensure the constant current of

water through the cylinder, a hollowed out lead plunger is attached to the lower part, which not only performs the duty of sinking the apparatus rapidly, but also serves to bring up a portion of any sediment or silt which may be at the bottom. The line attached to the cylinder is marked off in fathom lengths, so that the depth may at once be known. The instruments described have been employed by me in the collection of many waters from reservoirs and lochs, and in every case the waters collected at great depths agreed in chemical composition and properties with those lifted from the surface of the respective reservoirs or lochs.

5. *Effects of Filtration.*

All reservoir and loch waters are improved by filtration. Mechanical impurities, such as finely divided clay from artificial banks, and organisms of all kinds, are arrested in great part. Chemical impurities, however, such as the drainings of highly manured fields, or the products of decomposing sewage, are not removed by a mechanical filter. Any slight tinge of colour is lessened, especially if the filtering bed contain shells. There are two ways of determining the colour of water. The best method is to introduce the water into a testing tube, about 16 inches long and 2 inches wide, the one end of which is closed with a piece of plate glass. This apparatus has been in use for some years among all analytical chemists who have devoted attention to the subject of water analysis. The tube is filled with the water to be examined, and is held in the hand over a piece of white paper, while the operator looks down the whole length of the column of liquid. Different shades and degrees of colour can be very easily and correctly distinguished in this manner. Another plan which can be resorted to in all lochs and reservoirs, is to lower a white porcelain plate, about 6 inches in diameter, and observe the colour which the water imparts to the plate at certain depths, as also the exact depth at which the plate disappears from the eye.

MR. STANFORD said—On behalf of the Chemical Section especially, and on behalf of this Society generally, I beg to move a most hearty vote of thanks to Dr. Macadam for the very instructive and interesting lecture he has given us this evening, and also for the very kind way in which he has responded to our invitation to come from Edinburgh for the purpose. Many, no doubt, have wondered what Edinburgh could teach Glasgow on this subject. There is no

doubt that this city is as far before other cities in the purity of its water supply, as it is far behind them in the disposal of that water supply after it has been fouled into sewage. The question of water supply naturally divides itself into quantity and quality. The question of quantity is an extremely difficult one, but it is one of engineering, and therefore generally a question only of pounds, shillings, and pence. I should like, however, to remind the engineers that we are far behind the ancients in the quantity of our water supply. We have no modern city which has anything like the supply of ancient Rome. With regard to the quality, it cannot be too often enforced upon the public that they are the very worst judges of what a water supply ought to be in point of quality, because the two tests of taste and appearance are, as Dr. Macadam has shewn us, the most fallacious that can be relied on. The result is, that it often happens in a country village that the analyst who insists on a certain well being shut up, is at loggerheads with the parochial board, or with that village nuisance, the "oldest inhabitant." This individual appeals to his healthful appearance, and says he has drunk of the water, man and boy, for fifty years; and it is of no use to tell the parochial board that the man has lived so long in spite of that water, and not in consequence of it. Taste is extremely fallacious. I may mention a curious instance of this which occurred during the great cholera outbreak in London. There was a well, now shut up, which had disseminated the cholera over a wide district, because the water was bright—so sparkling that the neighbours sent for it far and wide. The rainfall from a churchyard drained into it, and in this churchyard a number of cholera patients had been buried. At a place near Woolwich a soup-kitchen was established, where they had a good well with plenty of water. The water was bright and sparkling, but it was found to have one unfortunate drawback—it would not make pea-soup. The water contained a large quantity of sulphate of lime, which formed an integument over the split peas; so that they refused to split any further. Another instance occurred at one of the stations on the Birmingham and London Railway. The Railway Company thought that the local Water Company charged too much for water. They therefore sank a well, but before the engines had taken water from it for a week, they found it "furred" up their boilers. I suppose the reason why the passengers did not find out the quality of the water so soon was, that they seldom drank it without its being qualified. It was found, however, before many weeks, that the people who refreshed at that station were often seized with diarrhœa before they

reached London. The Company were, in fact, administering an excellent aperient. The estimation of the purity of water is entirely a matter for chemists to determine; and I repeat that nothing but a rigid and exhaustive analysis can be trusted. I beg to move a cordial vote of thanks to Dr. Macadam.

MR. BROMHEAD—I think it would be interesting to mention that within the last two months the Corporation of Glasgow have issued instructions that there shall always be a ball-cock in a cistern. This involves an expense which would be something like £10,000 a-year to Glasgow in the shape of plumber-work. It is a great inconvenience that people should be always forced to put on such a construction. I think that going back at the present time to an obsolete affair of that kind is a very great mistake.

MR. J. R. NAPIER—Dr. Macadam mentioned that the west end of Edinburgh was supplied with 60 or 80 gallons per head. May I ask how it was measured?

DR. MACADAM—Water meters were put upon the "mains" leading to certain districts, and the number of inhabitants being known, the quantity per head was calculated. The experiment was conducted by the engineers.

Thanks voted.

IV.—*On the Economy of Fuel in Domestic Arrangements.* By MR. JAS. R. NAPIER, F.R.S.

[Read before the Society, February 4, 1873.]

THE object of the present communication is to call attention to some economical results which I have obtained with apparatus for heating rooms and for boiling water.

Before, however, alluding to these, I desire to make a few remarks on some existing systems. The difficulty in heating rooms hitherto has been to get an abundant supply of fresh air introduced along with the heat at a moderate temperature and imperceptible velocity.

Although neither physicians nor chemists have yet been able to tell us the exact amount of depreciation which our lives sustain by living in an atmosphere the amount of impurities in which is known, we are all sensible of the pleasure of living in a pure one; and,

therefore, desire as much of that as we can get when the temperature suits us. In general, it is either our ignorance or our poverty which prevents us from taking more of the pure air then than we do. The fact of so many people leaving our populous cities and going to the coast or country in summer, and so many leaving Britain during its dismal winter for the sunnier regions of Madeira, or the shores of the Mediterranean, shews at least a desire for a purer and milder air, which could not be gratified at home. For we have not yet found a system as economical as we wish for heating in winter an unlimited supply of fresh air to the temperature of a British summer, or a Maltese or Alexandrian winter. The quantity of fresh air which we require to be passed through our rooms so as to maintain vigorous health in them, must depend on the efficiency with which the vitiated air is removed from our persons, and on the temperature at which the fresh air is supplied. We refuse to take much of it cold, and desire more of it when hot. Evidently, if we would invent and be at the trouble of using some sort of breathing machine, acting like a pump, by which the pure air could be inhaled through one set of very easily moved valves, and the impure be discharged into a waste conduit or sewer by another set, very much less air would suffice than we find necessary at present, discharging, as we do now, the vitiated air into the same chamber among the fresh air we have to inhale. Probably the calculated quantity of 200 to 250 cubic feet per hour might then be sufficient, but very much more is by present arrangements found to be necessary. The open fire and chimney usually gives us as much fresh air as we like, and often more, in the cold state, and always a great deal less of its heat. Its cheerfulness, which so many people say they delight in when a close one is proposed as a remedy for one at least of these evils, is so clearly a delusion, or has nothing whatever to do with the object of a fire, as scarcely to require refutation. A bright fire on a hot summer day is not generally considered a cheerful object, nor does the stoker of a steamer consider that his furnace has a very cheerful look about it with the thermometer in the stoke room at 150° F. It is clearly the heat of the fire and not the sight of it which makes one cheerful or otherwise. When comfortably warm no one ever thinks of a fire or its flickering flame.

About the beginning of the present century Count Rumford pointed out many errors in the construction of open fires, as then made, and shewed that the more they were closed the less troublesome and more economical of their heat they became. Nevertheless, many of them at present have all the faults which he

pointed out and shewed how to remedy. Others, and notably Dr. Arnot, have since done the same. Fire-places entirely of iron, chimneys wide open, often without throats, or with valves or registers in them so inconveniently contrived as to be rarely used, are still very common.

The only real merit which an open fire possesses, besides its extreme simplicity, lies in the large amount of fresh air which it may cause to pass through a room; but this evidently is a merit only when the external air is either itself at the desired temperature, or is artificially heated; for when we are cold we object to cold currents passing over us, and prefer to be warm in an impure atmosphere rather than cold in a pure one. All improvers of open fires have virtually accepted this as a fact, the improvement desired being to make the room warmer. Rumford's consisted chiefly in contracting the chimney near the fire, and thus preventing it from drawing so much cold air through the room; for he reasoned that it was this cold air in its passage through the room to the chimney which abstracted the heat communicated by the fire to the walls, floor, furniture, &c., which made the room cold, or prevented its being heated. And his reasoning is still assumed to be good. Dr. Arnot carried the principle of chimney contraction to the limit of smallness in his stove or close fire, and obtained a certain amount of ventilation by means of his valve opening into the chimney near the ceiling. He could thus cause to pass through the room any amount of fresh air he pleased, to the limit which the area of his chimney and its temperature permitted, and he could also make the room as hot as he pleased by allowing the fire to burn more or less fuel. Such is what I profess to be able to do now with simpler apparatus.

Arnot's smokeless open fire was, I conceive, an attempt to meet the prejudice in favour of the so-called cheerfulness. The throat was very small and close to the fire, the absence of smoke permitting it to be smaller than usual.

Apparently the most successful of open fires—successful in that the fire differs, or needs to differ, in little or nothing from an ordinary open one, and that it supplies the room in which it is placed with a large amount of fresh air, moderately heated—is one which has been improved by Captain Douglas Galton.

The fire gases in passing up the chimney, and the heat from the back and sides of the fire itself, heat the fresh air, and the fire draws it into the room near the ceiling. It appears to me, however, to be an expensive method of heating a house.

The same expense, if applied in economical stoves or close fires, would do about three times the work. For the efficiency of one of the Galton fires, as tested by General Morin in Paris,—

Was only	34	per cent.	
While many close fires gave	90	,,	
And some	95	,,	
Or while the ordinary open fire lost	84	,,	of the heat,
The Galton fire lost	66	,,	,,
And close fires from	5 to 10	,,	,,

And the expense of preparing a chimney for one room would probably be as great as would supply an economical heating apparatus for the whole house.

One has only to take a view of the chimney-top scenery of Glasgow, to become aware of the utter inefficiency of its domestic heating arrangements. Instead of now having no smoky rooms, no back smoke, or other annoyances, and after proofs published upwards of seventy years ago of the cause and cure of these evils, we are apparently no better informed than if Rumford had never lived, and so simply proved all he said. This is self-evident from the number and curious variety of additions to the chimney-tops of houses everywhere to be seen, and every one of which would be unnecessary if Rumford's precepts were followed. If the fire-places themselves were properly constructed, architects would have the satisfaction of seeing their fine designs remain as they intended them. I have here an illustration of this kind of unnecessary disfigurement and indication of internal discomfort. [Here a photograph was exhibited, taken from the back of a fashionable West-end block in Glasgow, where, in one house in particular, nearly every variety of the smoke doctor's art is to be seen.]

The public generally must, indeed, have some very curious ideas as to the effect of lengthening a chimney, when a few feet of open-jointed tubing or even a close-jointed tube is expected to make a bad one answer better.

If the velocity in the chimney increases as the square root of its height, as it is believed to do, the gain of adding one, two, three, or four loose cans, of about one foot in length each, to the height of the chimney, must be next to infinitely little, to say nothing of the danger in storms, or the right of any one to increase a chimney in the same stack, for his own benefit, above that of his neighbours to their injury; for as a blow-down is caused by some object—a neighbour's taller chimney, it may be—intercepting the wind and deflecting it down, for which no cure has yet been found, and is not likely

to be found until the winds are made permanent in force and direction, except the self-evident one of raising the chimney-top above the downward current into the horizontal one, so surely no one can have the right to create these downward currents in their neighbour's chimney by raising their own.

In general most rooms with open fires are, during the day, supplied with sufficient fresh air, at least we then complain more of the want of heat in them than of air; but at night, when the gas is lighted, it is far otherwise. It has been shewn by eminent chemists that the great destroyer of fresh air in our houses is the gas burned. Jets using 5 cubic feet in an hour making the air, according to Roscoe's evidence, as impure as eight or nine people would do in the same time. Yet how few even of the wealthiest take any trouble to remove this vitiated air. They live, as it were, in elegant gas stoves. They give sumptuous entertainments in them, with the most expensive and purest of wines; but decline to give pure air that their friends might, as was practically demonstrated by Dr. Boswell Reid in his experimental room in Edinburgh, enjoy their hospitality in the highest degree, perhaps for the brilliant reason that it would look ugly to put a pipe through the room to remove the vitiated air. I expect, however, that a shortened life and a weakened constitution, or the loss of a dear friend, from living in these impure atmospheres, will be admitted to be a vastly greater evil than an ugly pipe—although we have yet to learn that anything which does its work in the simplest possible way is necessarily an ugly object, or worse than that which kills one—viz., no pipe at all. If they estimate the amount of gas they consume at 10 or 12 cubic feet in an hour in rooms of about 5,000 cubic feet of volume, they will find, if they believe Roscoe, Angus Smith, and others, that they are destroying as much air for vital purposes as twenty to twenty-four people would do. The hot gas accumulates near the ceiling till it cools and falls, and is breathed by all above the level of the fire opening, if not also by some who may be below it, if, as many believe, a mixture or diffusion of the gases has taken place.

We hear occasionally of some one having caught cold on coming out of a crowded room, perhaps a brilliantly lighted ball-room, and dying shortly after of consumption. I could far more readily believe, with an American writer, if the explanation is so simple, that it was not by coming *out* of the hot room into a cooler atmosphere, but by going *into* it, that caused the death, which would have happened sooner and more certainly had the person remained

longer inhaling the already used-up air of so many people and gas lights in such absolutely unventilated places.

I might here refer to the question of over-crowding, which, to my mind, is very much less a question of the capacity of the room, than of the quantity of pure air which each occupant can get. A room may be over-crowded, however large, in the only sense in which a corporation has any right to interfere—if it has no outlet for vitiated air—if it is close and already full of vitiated air, either from previous occupation or from gas burning; and a room, however small, may sustain vigorous health, if abundantly supplied with pure air. A crowded open-air meeting is not considered unhealthy; and many live for hours, and do wonderful work, with their heads closed up in rooms or spaces very little bigger than their own heads—in both they have plenty of fresh air. It appears to me that it would be a vast deal wiser policy, so to frame the law as, that science should not be ignored, to license lodging houses not by their capacity, but by the volume of pure air with which each was able to supply its inmates, when, like the purchasers of Glenfield Starch, it might be the duty of the corporation to "see that they got it." I see no reason why lodgers should not be allowed to lie on shelves, one above another, in as many tiers in height as they were pleased to mount up to, provided each had a sufficient allowance of pure air. I see no reason why, if a lodging-house keeper or public company chose to erect a St. Rollox chimney, or blowing engine of 1,000 horse-power, and by that or other means supplied so much air that the inmates might pack themselves as close as tiers of coffins, why they should be prevented from so doing; and if the keeper or company, at the same time, supplied the air at a moderate temperature, I expect that the inmates would be vastly more refreshed after a night's rest there, than many of them are in the licensed rooms of a certain volume.

Dr. Arnot provided means for the removal of some at least of this vitiated air by his self-acting valve near the ceiling; but in very few open fire chimneys, as at present constructed, other than his, can even this imperfect system be applied. The throats below are too wide, or have very inconvenient and unsatisfactory means of being reduced, whereby so much cold air, as Dr. Arnot has himself stated, is there admitted, that little power is left above for opening and shutting valves, or for drawing any vitiated air whatsoever from the upper part of the room, and more frequently admitting smoke there. Moreover, neither is Dr. Arnot's valve, nor probably the chimney itself, large enough thus to remove all the hot vitiated

air, where so many currents are at work to mix and diffuse it through the room, and pollute the fresh entering air. The only sure and effectual method of removing vitiated air, whether from burning gas or from the person, is, as General Morin has stated, to make provision for its escape *at the place where it is generated.* Therefore, for gas burned, this provision should be made *at the gas-burner itself*, where a very small orifice will suffice, and with this great advantage also, that a much smaller quantity of fresh air is then wanted; for it will now be pure and unmixed with vitiated air, and therefore less fuel will be required to warm the room, when the chimney or fire has been properly constructed.

In order to remove these products of gas combustion, according to General Morin's principle, before they became mixed with much of the purer entering air, to remove all, in fact, that was rendered impure by the gas at the least cost, and at the same time retain a sliding gasalier, the lights of which, for experimental purposes, could be pulled down to the table, I had the arrangement seen in fig. 1 executed. Tinned iron hoods or cones, about 12 inches in diameter, were placed about 4 inches above the base of the gas-jets, and connected with a pipe 2½ inches diameter, leading to the chimney, where it rested in a spherical cup, the end of the pipe being a right cone. By this means the lights can be raised or lowered at pleasure, and the products of combustion escape at all positions in their most concentrated state. The success of the arrangement was so complete that something of more elegance was attempted for another room. It has also been a great success. The large glass bell, fig. 2, instead of the tinned iron hoods, allows the ceiling to be lighted. I was aware of a well-advertised London patent for this purpose, but it was much too complicated, expensive, and troublesome for my ideas of what was wanted, and I did not see the philosophy of paying for gas, and then wasting about $\frac{1}{5}$ of it by ground or clear glass globes. Many plans fail on application, although the principles involved may be correct. I remembered that a cousin of my father's had a plan, nearly 40 years ago, with a glass bell and argand lamp, with a small pipe leading to the chimney of an open fire, but his bell constantly dropped water. The only real difference in the plans was, that where he had a very small pipe, I have a relatively large one leading to the chimney. Where he had probably a wide throat to his chimney, I have a narrow one in the open fire.

In illustration of the correctness of these views of General Morin, I tried the temperature of the upper part of my dining-room, near the ceiling, on several December evenings, three years ago, about

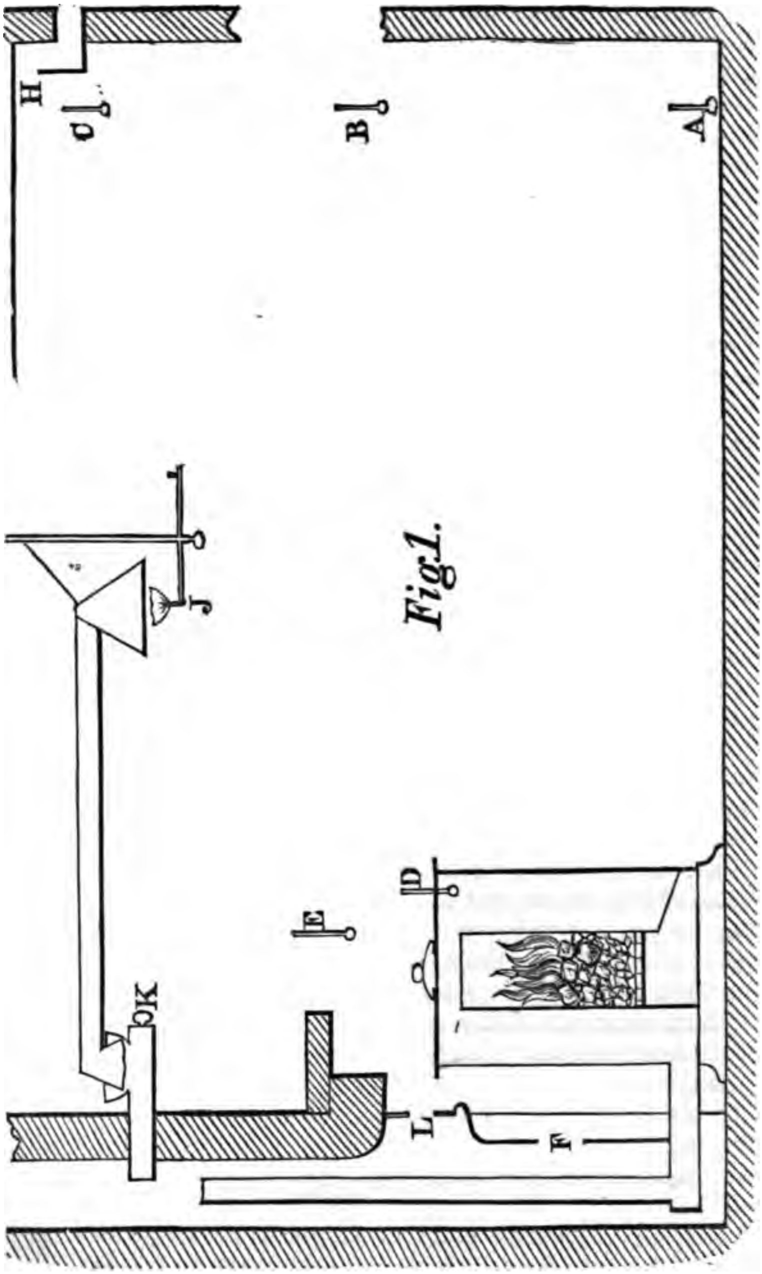


Fig. 1.

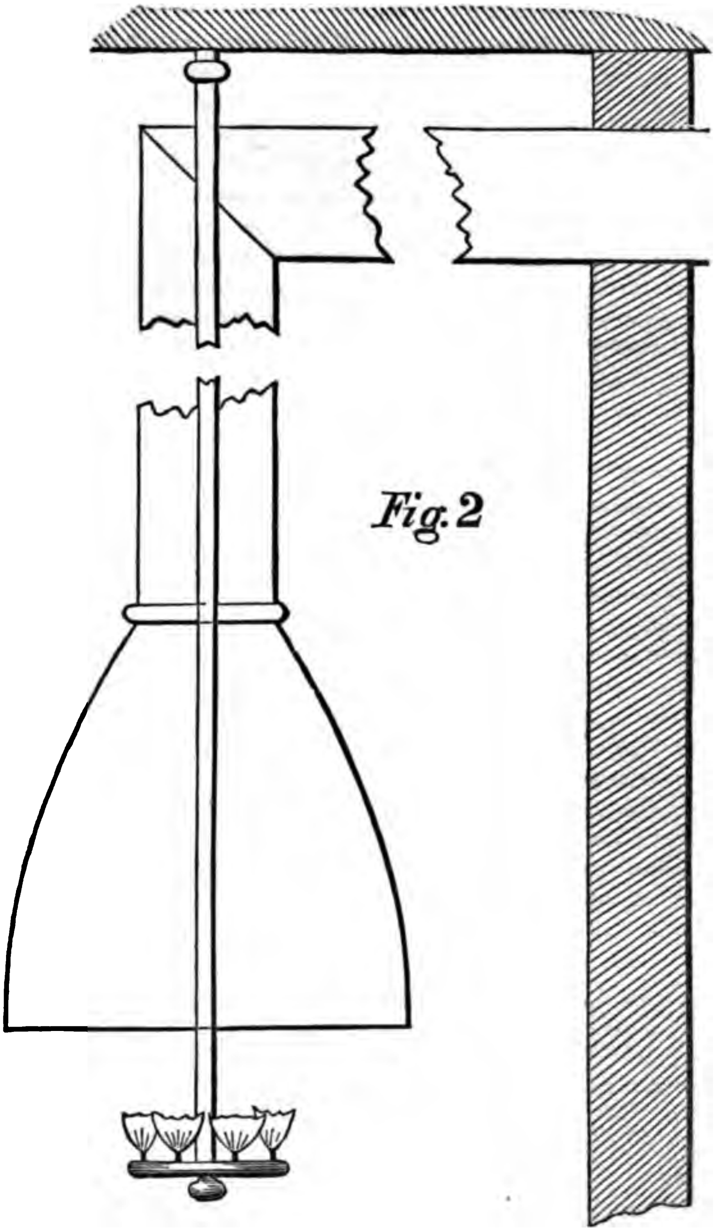


Fig. 2

	TABLE A.	F., or Fahrenheit Degrees above the Freezing Point of				E	D	A	B	C
		Air Current, &c., 2½ in. above Stove.	Outside Air.	Air Entering Hall.	Hall.	Air Current 12 in. above Stove.	Stove Gases at Top	Floor.	4½ ft. above Floor.	Ceiling.
A.M.	25th January.									
8	Light gas, two large jets, J, .	...	6	8	12	...	...	...	22	...
·10	Light fire, with ½ lb. charcoal. Ash-pit open, ...	...	...	...	...	...	...	...	...	...
·20	About 8 lbs. gas coke are in stove, and gas light extinguished, . .	...	...	...	...	...	...	...	...	...
·50	11½ lbs in all charged since fire was kindled,	...	...	...	...	...	230	...	23	...
·55	. . . . . .	...	...	...	...	...	218	...	...	...
9·10	. . . . . .	...	...	...	...	...	214	...	24	...
·45	. . . . . .	...	...	...	...	...	262	...	25	...
	. . . . . .	...	...	...	...	...	...	...	...	...
10·15	41 square inches L opened into base of chimney, and left so till 6·45 P.M.; also 5 square inches at gas ventilator K left open unintentionally till closed at 1 P.M. Ash-pit slightly opened, . .	...	8½	...	...	...	266	...	...	...
·25	. . . . . .	...	...	...	...	...	290	...	...	...
11	. . . . . .	..	9	10	16	...	318	...	25	...
·20	. . . . . .	75	...	...	...	...	307	...	25	...
·35	. . . . . .	84	...	...	...	...	338	22	25	25
12	. . . . . .	96	...	...	...	...	362	23	26	27
P.M.										
·25	. . . . . .	97	11	...	...	...	396	24	26	28
·45	. . . . . .	112		...	...	...	416	24	27	28
1	Ash-pit and gas ventilator K shut. 41 square inches L at base of chimney left open till 6·45 P.M., . .	100	...	...	...	...	436	...	...	...
·8	. . . . . .	92	...	...	...	...	366	24	27	29
·22	. . . . . .	92	...	...	...	...	331	...	...	...
·35	. . . . . .	...	..	...	...	...	310	...	...	...
2	. . . . . .	...	12	...	...	40	307	25	27	28
·30	. . . . . .	...	...	...	...	46	316	25	27	28
·45	Open ash-pit slightly, . .	...	...	...	...	...	316	...	...	...
3·15	. . . . . .	...	...	...	...	46	354	25	27	28
·25	. . . . . .	...	...	...	...	...	358	...	..	...
·30	. . . . . .	...	...	...	...	...	368	...	...	...
4	. . . . . .	...	...	...	...	47	357	24	27	29
·30	Light gas, and open its ventilator, .	...	11½	...	...	...	352	24	27	29
5	. . . . . .	...	...	...	...	50	320	26	30	31
6	. . . . . .	..	...	...	...	42	264	26	31	32
·37	. . . . . .	...	...	...	...	38	235	27	31	31
·45	Shut ventilator at base of chimney. The only ventilation during remainder of experiment being the 5 square inches at gas ventilator, . . .	...	...	...	...	...	224	...	...	...
7·9	. . . . . .	...	...	...	...	...	...	...	...	...
·45	. . . . . .	...	...	...	...	...	198	27	31	31
8	Fire nearly out, . . .	...	...	...	...	...	166	...	...	...
·30	. . . . . .	...	12	...	...	...	118	27	31	31
9·23	. . . . . .	...	...	...	...	...	96	26	31	31
·35	. . . . . .	...	...	...	...	...	...	...	30	...
11.10	. . . . . .	...	...	...	...	...	...	...	30	...
and at 5·30	*on the morning of* the 26th January,	...	14	...	16	...	...	...	24	...

six hours after gas-lighting, when no ventilation of the upper part existed, and found it 11° hotter than on the floor, being 60° F. on the floor, 71° F. near the ceiling; while there was little or no difference during the day—nothing, at least, appreciable by my thermometers. I then made provision for removing the vitiated air from the burned gas in the way described; and now, when the same experiment is made, under similar circumstances, there is only between 3° and 4° of difference when the stove alone is in action, and about 2° with the gas alone, after six hours' lighting, and the stove cold. I reasoned that it was the *products* of the gas combustion which heated the ceiling 11°, and which consequently was vitiating the air, making it unfit for use.

The record of an experiment, made 25th January last, may convince others. Fig. 1 shews a section of the room, with the position of the thermometers, stove, &c. Thermometers were placed at A, B, and C, on the floor, 4½ feet above floor, and about 15 inches from the ceiling. Columns A, B, and C of table A shew the results obtained. The temperatures are given in degrees above the melting point of ice, the boiling point of water on the same scale being 180°. This alteration of Fahrenheit's zero point I have preferred for the reasons given to this Society in a former paper, and I have called it F_0 instead of F. By adding 32° to the numbers in the table, the ordinary Fahrenheit scale is obtained.

I would remark here, in reference to fig. 1, and to columns A, B, C, of table, that a large amount of air was drawn from the room by the ventilator at F, that the fresh air from the hall, which might have been previously heated, but was not, entered at H, near the ceiling, and that, except when meals were served, I was the only occupant of the room, and the room-door was usually shut.

Having now shewn some of the objections to open fires, and that much more heat can be obtained from close ones, with a better system of ventilation, I shall refer to my own schemes for making them simple and easily managed. A number of years ago I was much struck with a remark of Péclet's, in his *Traité de la Chaleur*, that if a small fire were placed under an immense number of vertical tubes in a boiler, the heated gases would ascend only a very few of them—the air in the remainder would either be stationary or have descending currents; but if the fire were placed above and the heated gases made to descend, they would fill all the tubes equally; or, as we may otherwise state it for the present purpose, if we wish to prevent a hot or lighter gas escaping, we must have no opening in the upper surface of the containing vessel

—the lower surface may be free but not the upper. The fact is well known and applied in many businesses, but very seldom to domestic heating arrangements. Make a large enough chamber, let the hot gases enter it near the top and escape by the bottom, when a regulating door on either the inlet or outlet pipe will control the combustion, and nothing can escape till it has done its greatest duty. The founder's drying stone, the iron shipbuilder's heating furnace, are applications of the principle. Fig. 3 shews the means I have taken to apply it to heating rooms. The fire is placed near the lower part of a central tube; this tube is covered by a much larger case placed over it like an extinguisher, close at the top, open at the bottom. The fire gases ascend in the central tube and descend in the surrounding case, escaping into a flue at the bottom. A stove of this construction, having about 24 square feet of heating surface, and burning gas coke at the rate of about 1 lb. an hour, in a room of about 5,000 cubic feet of capacity, makes it hotter than about 30 lbs. of the same coke did with one of those isolated American box-fire places. The coldest gases being below escape first, and only after they have given out the greatest amount of heat of which they are capable, with the given amount of surface. The whole surface is effective for heating—top, sides, and bottom. When gas-coke is burned in it at the rate stated above, the temperature of the smoke in the upper part of it rarely exceeds 350 F_o., and this raises the temperature of the room in which it is placed about 5° with the room door opening and shutting as may happen, and an opening into the hall near the ceiling of about 80 square inches for the fresh air to enter or the hot air to escape by. The room is better ventilated with about $\frac{1}{3}$ of the fuel formerly used, and at about $\frac{1}{6}$ the cost, for gas-coke, the fuel found to be most suitable for it, is about half the price of coal. There is less dust, and no attention during the day is required—one fire in the morning lasting all day. On 31st January last, about 15 lbs. charged at 7 in the morning was still red at 11.30 P.M.—the gas in the upper part of the stove having during that time a mean temperature of about 300 F_o., that of the room till gas-lighting about 5 P.M., about 30 F_o., and from 5 P.M. till 11.30 P.M. about 34 F_o., and at 11.30 P.M. the gas in top of stove was 140 F_o. In general, the fire is out by about 6 P.M., the two gas lights consuming about 12 cubic feet or $\frac{4}{7}$ lbs. gas per hour, keeping up the temperature for the rest of the evening, and doing nearly as much duty as 1 lb. coke in the stove. It is very easily kindled with about $\frac{1}{2}$ lb. wood charcoal, and as easily

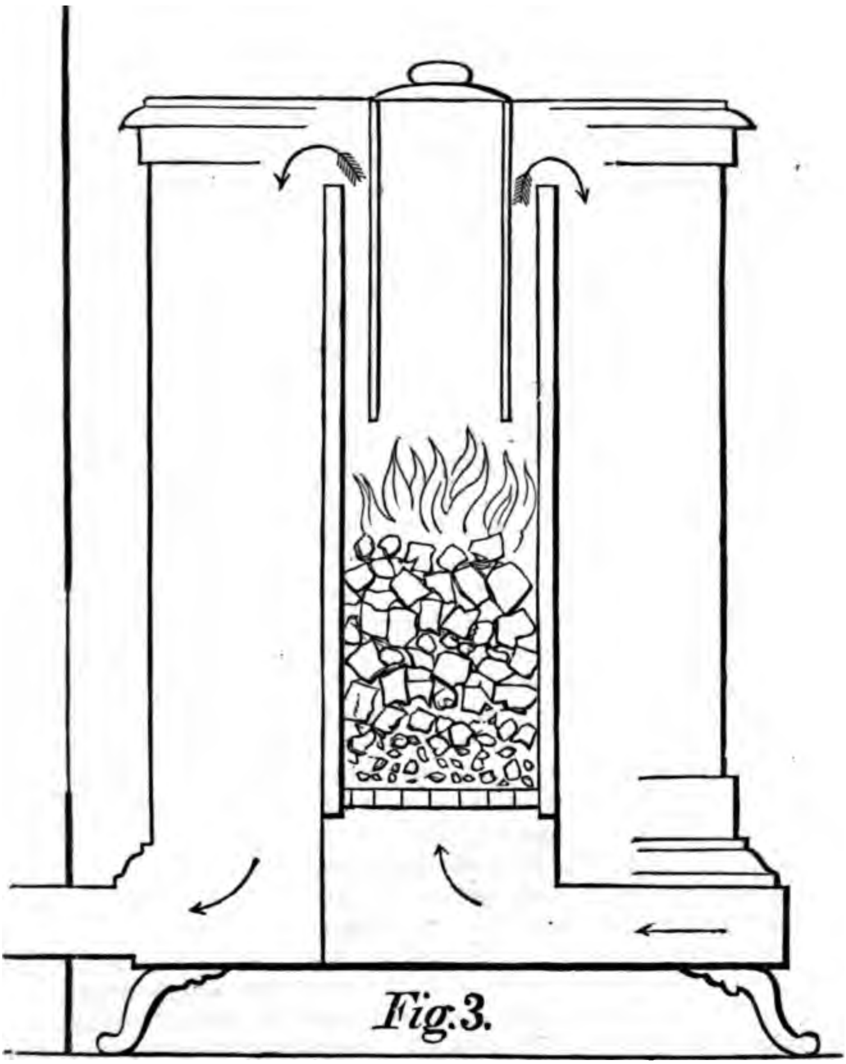


Fig. 3.

cleaned after use by merely pulling up the grate and allowing the contents to drop into the ash-pit. The experiments recorded in table A shew the working of the stove on 25th January last. A thermometer, D, fig. 1, was inserted in the stove itself with its bulb 2¼ inches from the top, so as to get an idea of the maximum surface temperature; another, E, was placed 2½ inches above it, and afterwards shifted to 12 inches. The ventilator, L, was opened

and left open, not from any necessity or feeling of oppression or desire for more air, but merely to perceive its effect that the result might be recorded. The result was that I felt chilly all day on the side not next the stove, caused evidently by the colder fresh air current entering at H from the hall, and passing over me on its way to the chimney ventilator, L. And, also, that I would have preferred a warmer room, which I could easily have got in two ways, either by reducing or entirely shutting the ventilator, L, at base of chimney, or by opening the ash-pit and burning more fuel. I preferred the former during the day, seeing that as far as one's feelings tell, it is always then fresh; and we have not yet got a power of controlling the heating effects of the gas-lights, which, when the room is sufficiently hot during the day becomes too hot at night. A temperature of 30° to 32° F_0. is agreeable to me, at 34° and upwards I desire more fresh air. The thermometers were not compared at Kew, but were, with the exception of that in the stove gases, cheap spirit ones, whose Fahrenheit zeros I had shifted 32°—they agreed fairly with each other at the temperatures recorded.

That stoves or close fires should be blamed for over-heating or burning the air, making it disagreeable to the senses, is surely not due to the fact of the fire being closed. General Morin and others have so often pointed out the unhealthiness of red hot stoves, that it seems almost childish to say that if the fire is in a close case of sufficiently large dimensions it would be impossible to make the case red hot, as impossible as to make the poker lying at the side of an open fire, or the wall on the opposite side of the room red hot. Evidently, with a case as large as the room itself, its surface temperature would be the same as that of the wall. Indeed, there is no difference whatever between an open fire and a close one in this respect, for let a screen of any kind be placed between you and an open fire, and immediately, as far as you are concerned, you have a close fire with the screen radiating its heat to you and giving off hot currents as an open fire does from the floor or wall. Although the commissioners of 1857 reported "that the radiation from close stoves is small . . . and differs materially from the circulation produced by an open fire, the heat radiated from which is great," I submit that if the radiation is small, it must arise simply from the fact of there being less fire inside to radiate from. But I deny that the radiation is small. It must be at least three times greater than from an ordinary open fire burning the same amount of fuel, and which has only about one-third the surface exposed, whereas,

in an isolated stove, the whole of the surface is exposed. The whole surface radiates, and at any intensity of heat we please, according to the size of case we make, relatively to the rate of combustion inside.

It must then be from ignorance if any one purchases a stove which makes the air disagreeable, purchases one too small for the amount of fuel which he intends to burn in it, or if he burns too much in the one which he has purchased. It must be admitted that a room heated by a large surface at a low temperature must be more uniform in its temperature, and that more nearly agreeing with the temperature and freshness of a British summer or Mediterranean winter than if heated by a small surface at a high temperature, in which every variety of climate may be experienced in a few seconds, according to one's position in the room. Then, surely, if health is the object sought for, one ought to prefer those stoves which have a large amount of surface.

But business is not necessarily science. Anything sells if it is cheap enough. So all kinds of stoves are to be found in the market, except one with a sufficiently large surface (in the British market at least) for the fuel to be burned in it. Those who are wise enough to take advantage of the large experience which General Morin has published will perhaps be guided by his advice, and select one which has at least six square feet of *effective* heating surface for every 1,000 cubic feet of space to be heated and ventilated by it.

As my neighbours right and left keep some of my rooms nearly hot enough for me, my dining room, before the stove is lighted, being generally from 14° to 16° hotter than the external air, I am not able from my own experience of the stove I have described, to corroborate General Morin, except so far that I think 24 square feet of effective surface too little for a room of 5,000 cubic feet of capacity, and for such stoves (fig. 3) I conceive that the rate of combustion ought not to be allowed to exceed $\frac{1}{20}$ lb. of coke per square foot of heating surface per hour.

For want of means to measure the quantity of air passing through the room, I have not been able to state more definitely what the duty of 1 lb. of coke in it is; but from the low temperature of the chimney at about 7 feet from the floor, 43° F_o, and the very small amount of air which reaches the fire through the bad fittings of the ash-pit door, wedged as close as I can make it, I conclude that it must be at least as efficient as any which General Morin has tested, and is probably 96 per cent., or that not more than 4 per

cent. of the heat is lost up the chimney. Any amount of ventilation which the chimney is capable of can be obtained by opening a valve at its base, the fresh air may be admitted near the ceiling, and a special tube for removing the burned gas may be led direct into the chimney. Such is the arrangement I have made for myself. (See figs. 1, 2, and 3.)

The base of the chimney, however, being close to and immediately behind a hot stove, is clearly not the best place for removing the vitiated air—it is simply a place where an opening can be very easily and cheaply made into it.

The instrument (a wind-mill arrangement) which I had intended using in order to ascertain the velocity of the air passing into the chimney, had such a table of errors sent with it, as to render its readings doubtful, and I have had no means of finding the true value of its scale. If, however, it is tolerably accurate, the chimney has a ventilating power, when the stove is consuming about 1 lb. per hour of coke, of about 6,500 cubic feet of air per hour, the velocity of the current at the exit, when this volume is discharging, being about 350 feet per minute. The 2½-inch tube ventilating the two large gas-jets, discharges about 1,000 cubic feet per hour when there is no other opening into the chimney, and about 700 of the 6,500 cubic feet per hour mentioned above.

The formula for such instruments should be of the form $V = C + N R$, where V is the velocity, C and N constants, and R the number of revolutions.

Being struck with the clean appearance of a patent asbestos and gas-fire, and the ease with which it could be lighted, I had the curiosity to estimate its cost, thinking that if it were economical to use it in the stove I have described: I give the result for the benefit of those who may think illuminating gas an economical method of heating or cooking. Assuming the total heat of combustion of 1 lb. of Glasgow gas (27 candle, I believe, it is called) at 21,000 units, and its density as given me by the gas-manager, Mr. Foulis, at 0·62 of air; then 1 lb. of gas will have 21·11 cubic feet of volume. If this is taken at 6d. the 100 cubic feet, its cost per ton will be £11, 11s. 6d.

Again, assuming the total heat of 1 lb. of coal as 15,000 units, and its cost £1 per ton, the relative cost of heating by coal to heating by 27 candle gas will be as 1 to 8·4; and if gas-coke be used instead of coal, the relative prices will probably be as 1 to 12, the gas being 12 times dearer. This is on the assumption that the best method of applying both are used; for it is easy to say that illumi-

nating gas is as economical as coal, if the best gas heating or cooking apparatus is compared, as it often is, with the worst coal cooking or heating fire. If gas-coke, however, is to be the fuel of the future, it would be well to have it supplied in the dry state, otherwise we shall have to apply to the City Analyst to know how much it is adulterated with water, for dry coke has certainly the power of holding $\frac{1}{4}$ of its weight of water. I recently asked the corporation to send me some *dry* coke, and it contained $2\frac{1}{4}$ oz. in the pound or $\frac{1}{7}$ of its weight of water. Commercial coke is therefore not dry.

The foregoing remarks as to heating and ventilating have reference chiefly to *existing* houses, and not as to what might or should be done for the same end in the construction of new ones. Every house, however, whether old or new, ought to be flooded with pure fresh air. A large fresh-air channel ought to be as much a part of the house as its front door, its windows, or its chimneys. The fresh air ought *not* to be allowed to find its way into the house as it best can, by chinks and crevices anywhere and everywhere, as these often make certain parts of the room uninhabitable. Those who are pleased to heat this large volume of fresh air in cold weather to a moderate temperature, in a chamber, before it reaches the rooms, will find their economy in increased health, and then the extravagant open fire will become tolerable.

I have now a few remarks to make on the boiling of water for domestic uses, and to describe a new cooking apparatus. The most economical results published on the heating of water, on the small scale, as far as I know, are those by Count Rumford. In his "Essays" he gives the results of numerous experiments, with the various alterations he made on his apparatus. The best he obtained was in a boiler containing 187 lbs. water, when 20·1 lbs. of ice-cold water was made to boil with 1 lb. of pine-wood fuel. This is equivalent to 3,618 units or lbs. raised 1° per lb. of wood burned. If we assume, on the authority of a table given by Rankine, the total heat of combustion of 1 lb. of dry pine-wood to be 7,245 units, Rumford obtained nearly half of the whole heat of the fuel in the water. From numerous experiments I have made with a kettle or boiler containing $2\frac{1}{2}$ gallons, which I have now to describe, I obtained, as the result of burning $3\frac{1}{2}$ lbs. of coal, 17·55 gallons of water, raised from the freezing to the boiling point, or

51·08 lbs. raised 180° per lb. of fuel.
9,194 units per lb. coal.
9·52 lbs. evaporated from 212° F. per lb. coal.

If we assume the coal used (chiefly carbon) to be equivalent to

14,000 units, I have obtained nearly $\frac{2}{3}$ of the total heat of the fuel in the water, and had I made the kettle or boiler in such a way as to try to get the highest possible duty, the probability is, I would have got considerably more economy; but my object was more practical.

I had obtained with it two days previously, as the result of burning 12 ozs. of wood charcoal, 6,650 lbs. water raised 1°, or 8,867 units per lb. of charcoal, or 49·2 lbs. water raised from the freezing to the boiling point, or 9·18 lbs. evaporated from 212° F.

The first result was obtained from the burning of 55 ozs. of fuel, consisting of—

	12 ozs.	wood charcoal;	
	21 ozs.	shale oil coke,	
	16 ozs.	Airdrie coal (blind),	
	6 ozs.	soft coke,	
	175 lbs.	water was raised from	40° to 212° F.
and	25 lbs.	,, ,,	40° to 100° F.

The rate of combustion was 10 lbs. per hour per square foot of grate, maximum rate being 20 lbs. The time occupied in boiling each of the $2\frac{1}{2}$ gallons varied with the kind of fuel used and state of the fire, as follows:—

$2\frac{1}{2}$ gallons boiled in	39	minutes	with wood charcoal.
,,	26	,,	with do. and shale oil coke.
,,	19	,,	shale oil coke.
,,	33	,,	shale oil coke.
,,	52	,,	Airdrie coal (blind).
,,	44	,,	
,,	79	,,	soft coke.

The experiment was continuous, and lasted five hours, the fire being constantly renewed with fuel when required, in the order given above.

Péclet, in his great work, gives the results of heating baths, from which it appears that very nearly the whole heat of the fuel was obtained in the water; and Mr. Kibble, in the heating of his conservatory, must have realised nearly the same result, for he has informed me that the temperature of the gases leaving his water-heater is but 1° hotter than the water entering it; but I am not aware that in portable kettles for domestic purposes, anything approaching the economy which I have obtained has been realised.

The sketch, fig. 4, shews kettle similar to the experimental one, and its connection with a cooking apparatus which I have recently designed and got partially made. It virtually forms the case of such

a stove as I have already described. It is, as it were, an inverted pot, with an annular water space for the lower part of the sides, and placed like an extinguisher over and round the fire. The fire was placed in a small crucible with its bottom cut off, and replaced by a grate.

> The area of the grate was $\frac{1}{13}$ square foot.
> The heating surface of kettle, 4·32 square feet.
> Coal burned per square foot of grate per hour, 13 lbs.
> Heating surface per lb. of coal per hour, 9·43 square feet.

The time occupied in bringing the water to the boiling point varied with the force and direction of the wind — the chimney being one seldom used, and much larger than necessary for the very small fire employed.

From these data it will be seen that the heating surface is upwards of seven times greater than that of an ordinary pot of the same diameter on a close cooking range, and probably from five to six times greater than in pots on an open fire; and from its construction the internal heating surface, at least, being all effective, none of the heat can escape till it has done the most work it can do for the surface exposed.

Fig. 4 also shews the means I have adopted for economising the waste heat for heating water. As this waste heat—or that which escapes, being used when any cooking is proceeding on the top of an open or close fire—is about $\frac{6}{7}$ of the whole heat, and as cooking is not always proceeding, although the fire may be burning for the cook's pleasure, I thought it desirable, if possible, to prevent the heat being wasted, by placing an annular boiler (*a a*) or water-heater round the fire, as the *outer* casing of the flue. In most modern kitchen boilers or water-heaters, it is the direct heat of the fire which is so used, although Rumford condemned such seventy years ago; but as extravagance is not yet considered a vice, or economy a virtue, such abominable waste is still tolerated.

The annular water-heater may be supplied from a cistern in the kitchen, or be connected, if strong enough, direct to the main, with hot water all over the house if need be.

Although this annular water-heater catches most of the waste, and that *alone*, it is clearly neither economical nor desirable that there should be any to catch; therefore none of these contrivances ought to be such as to be capable of heating baths, which can be so much more quickly, economically, and certainly heated by a boiler on purpose. Those who can afford the bath might see that they

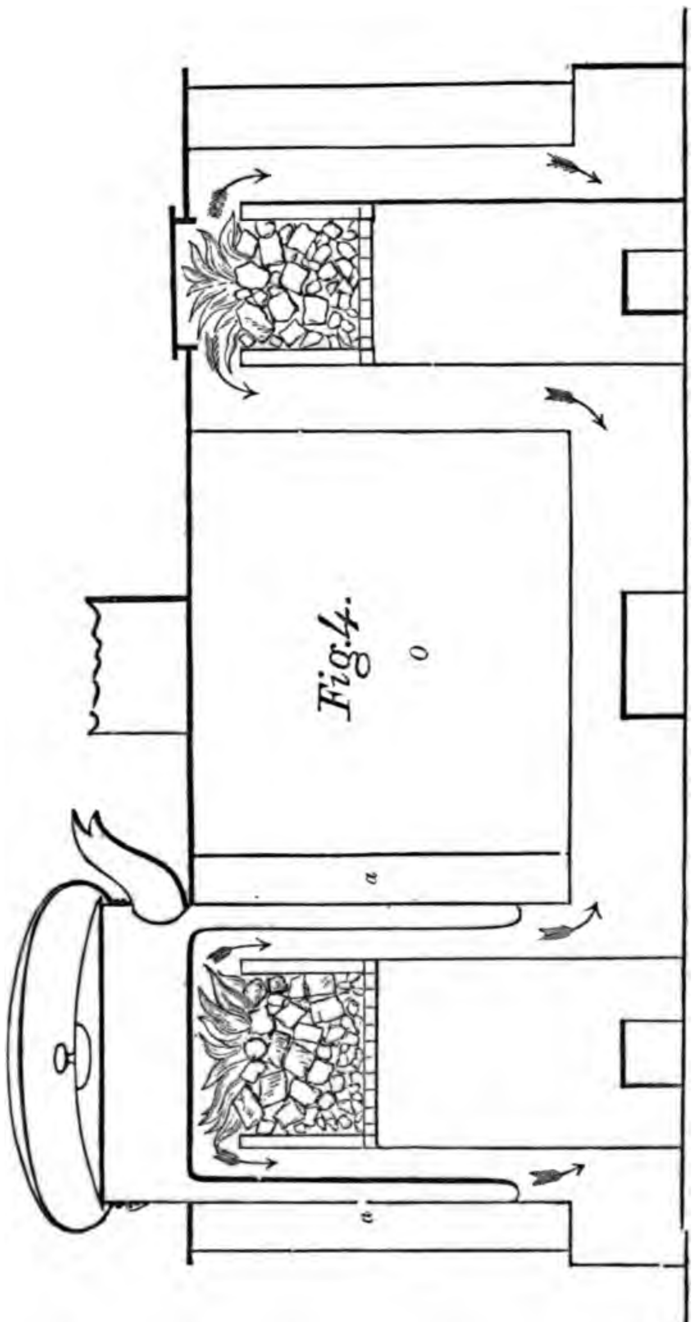


Fig. 4.

have the means of heating it as often as may be desired, which boilers behind open fires certainly do not possess. If these boilers were placed in the circuit of the water made hot by the waste heat, they would be most economical and useful.

Although I did not originally contemplate any greater economy from the oven (*O*, fig. 4), than in many other ranges, as my aim was to learn with how small a fire that operation could be conducted, I believe that it must be more economical than any other not made chiefly for roasting, simply from the fact that there is less heat lost in useless radiation from the upper surface, the only direct radiation from the fire being the opening left for the kettle, or a space of about 12 inches diameter. The oven is virtually the room in which such a stove as I have described is placed. I have tried it in a small way in my work-room, and succeeded to my own satisfaction. In a short time I expect to get the cook's experience of it and other matters, which may be recorded at a future meeting.

I shall now conclude by asking for information, which I have longed to possess, as to the cause of the desire we feel for more air when it is heated or above a certain temperature, than when it is cold, as all I have attempted to solve is the mechanical question of supplying a quantity of fresh air and heating it at the smallest cost. But it appears, if our bodies are cold we take very little of the fresh air if it is also cold—if our bodies are warm we enjoy the cold fresh air amazingly. If we are warm we desire far more of the fresh air if it is also warm, and we feel oppressed, sometimes, if the temperature of the room rises quickly 3° or 4° above 32° or 33° from the freezing point.

If our lungs are so elastic, that they would always inhale a definite weight of air, we might suppose that any one could travel from the lowest to the highest regions, or from the coldest to the hottest, without inconvenience; but the facts are against such a supposition. Aeronauts become insensible on a sudden elevation to five miles; and white people die of sunstroke, so called, when exposed in some manner to temperatures hotter than they have been accustomed to. If the lungs are not elastic they must work faster in the hot than in the cold atmosphere, and in the higher than in the lower regions, to do the same work, and such, to a certain extent, I am informed they do; but the ratio of the volume of a definite weight of air at 32° above the freezing point to that of 36°, being 1064 to 1072 nearly, is so much within our powers of breathing faster or slower as to make it tolerably evident that the temperature is *not* the cause of the feeling of oppression or desire for more air.

Physiologists might tell us whether the negro's lungs are relatively larger than those of the Esquimaux—whether the natives of the high plateaux of Mexico and Peru have relatively larger lungs than those of the Coast. They might help us to find a reason for this occasional feeling of oppression in a hot room. We might then possibly find a means of preventing it.

Dr. Allen Thomson, to whom I had applied for an answer to these and other questions, has kindly given his opinion in a note, of which the following is an extract:—

"UNIVERSITY, *4th Feb.*, 1874.

"I am sorry that, in the little time I have had to give to it, I have been unable to find any precise data to determine the variations of the respiration according to temperature of the air in the human subject.

"The general fact seems to be established that, as the temperature rises and the air is rarefied, the respirations become more frequent, and when the rarefaction is considerable, the amount of carbon given off from the lungs suffers diminution.

"But I do not think that within the ranges of temperature of which you spoke, as for example from 55° to 65° or 60° to 70° Fahr., the effect would be appreciable, or at all events constant: for a great many other circumstances would operate in compensating for, or interfering with, the simple effect of the rarefaction."

From this, and from a work by Dr. Lombard, which Dr. Thomson kindly lent me, it would appear that above a certain altitude the lungs of healthy strangers cannot work fast enough to supply their wants, and that this fact has been taken advantage of for the cure of consumptive patients. Their furnaces, which were consuming them below, not being able to get supplied with the same weight of oxygen in the same time above necessarily burn slower. Then the patient gets fat.

It is tolerably certain, however, that the oppression I have referred to is not caused by the want of oxygen arising from diminished pressure.

V.—*On the Economical Combustion of Coal Gas.* By DR. W. WALLACE, F.R.S.E., F.C.S., Gas Examiner for the City of Glasgow.

[Read before the Society, March 4, 1874.]

THE recent extraordinary increase in the price of coal, which, as regards the variety used specially for making gas, is likely to be permanent, has rendered necessary the very strictest economy on the part of gas companies and of corporations which supply gas. One result of this necessity has been, that the price of gas has been raised, in many cases, 50 per cent.; and another, that the quality of the gas supplied has been reduced as far as it has been considered safe to go in that direction. In most large towns, especially those in which the gas is supplied by the corporation, a standard illuminating power has been fixed by Act of Parliament; but previous to the rise in the price of coals, gas of a far higher illuminating power than that demanded by the Act was actually supplied. In the case of Edinburgh there are two competing companies, and of these, one, until very recently, supplied 30 to 32-candle gas, the other about 26, both charging the same price. Now, I understand, the standard of 26 candles is adopted by both companies. In our own city we had formerly two gas companies, both bound by Act of Parliament to supply gas of not less than 12-candle power; but the gas made by the old company actually had an illuminating power averaging about 28 candles, and was often above 30, while the new or "City and Suburban" company gave gas averaging 26 or 27 candles. In 1869 these two companies were taken over by the Corporation, who have since supplied Glasgow, and who are bound to give 25-candle gas. For two years or so the illuminating power averaged about 28 or 27½, and last year it was about 27. This year the average of all the works is something like 27 candles; but it varies a little, some of the works (of which there are now five) giving systematically a slightly higher standard of illuminating power than others. Although it is no part of my present purpose to discuss the local bearings of the question, I may state that, in general, the gas is of higher illuminating power, and more regular

in quality, when made in one or other of the smaller works, than when produced in the larger establishments. At the Dalmarnock works it is necessary, during the winter months, to carbonise about 400 tons of coal daily, and it has sometimes occurred that a large portion of the coal has been taken direct from the railway trucks, often dripping with water, to throw into the retorts. In the new gasworks at Dawsholm, near Maryhill, which, when completed, will be about as large as all the previously existing works put together, a very large space has been set apart for the storage of coals, so that these may be always used dry and in good condition.

The tendency, as I have already stated, has been to advance the price of gas and to lower its quality, as far as Acts of Parliament will permit; and the question naturally arises, whether gas is commonly burned so as to bring out its greatest possible value. We talk of gas being 25 candles, but that does not by any means imply that any jet of that particular gas will give the light of 25 candles. This is what the Glasgow Gas Act, 1869, says (page 38):—"All the gas supplied by the Corporation shall be at least of such quality as to produce from a union jet burner, capable of consuming 5 cubic feet of gas per hour, under a pressure equal to a column of water ·5 of an inch in height, a light equal in intensity to the light produced by 25 sperm candles of 6 in the pound, burning 120 grains per hour."

Here we have defined—*1st*, the quantity of gas to be burned in an hour, namely, 5 cubic feet; *2nd*, the kind of burner to be used—a union or fish-tail jet; and *3rd*, the pressure at which the gas is to issue from the burner—five-tenths of an inch of water pressure. I do not know by whom that clause of the Act was framed, but it is an excellent one, and fully recognises a point which I will endeavour to illustrate to-night—namely, that in order to bring out the real economic value of the gas, it must be burned at a comparatively low pressure. It will give you some idea of the size of the burner which I find it necessary to employ in order to comply with the Act of Parliament—it is a No. 8—that is, a jet which, under ordinary circumstances of pressure, is expected to consume no less than 8 cubic feet per hour, but which, when exactly regulated to half-an-inch of pressure, burns as near as possible 5 cubic feet.

Before entering upon the main business of my paper, I wish to say a few words on the comparative price and quality of gas supplied in different towns, as I think there is some misapprehension on the subject which it would be useful to correct. Take three towns—Glasgow, Manchester, and Birmingham. In Glasgow

the illuminating power of the gas is, say, 26 candles, which is really under the average, and the price 5s.; in Manchester it is 20 candles, and the price 3s. 8d. (outside the town 4s. 2d.); in Birmingham it is 15 candles, and the price 3s. to 3s. 6d. Now, it is easy to calculate from these figures the relative values of equal quantities of light, as given by the combustion of gas, in the three towns. Let us take the Glasgow gas as the standard, 26 candles being worth 5s.; then Manchester gas is worth 3s. 10d., and Birmingham gas 2s. 10½d. As regards price, therefore, the Glasgow gas will, considering its quality, bear favourable comparison with other towns, even those that are considered the most fortunate in this respect. But some of our citizens say, I do not know nor care anything about your illuminating power or candles, but I go to Manchester and Birmingham, where the gas is cheaper than it is here, and I find those towns as well lighted as our own, if not better, and the gas flames appear to be as large and to give as much light. The first answer I have to give to such assertion is, that no true comparison can be made between two lights, unless they are seen at the same time; and that, even if the flames are side by side, the comparison is useless and misleading, unless the same amount of gas per hour is burned in each jet. The size of a gas flame does not depend entirely on the quantity of gas consumed, but also upon the quality: two flames may be equal in size, and yet the one may be burning twice as much gas as the other. A jet of a given size, and at a given pressure, will pass much more of a light gas than it will of a heavy one; and the gravity of coal gas varies in proportion to its richness in those constituents upon which the illuminating power chiefly depends. But the size of a flame does not only vary with the gravity of the gas, but with the proportion of heavy hydrocarbon. When gas contains a little air, not only is the illuminating power immensely reduced, but the flame becomes comparatively small; and in like manner, the flame of a poor gas is small compared with that of a rich gas, the amount of each being the same. If, then, it be a fact that the gas flames are as large in Birmingham and Manchester as here, it only proves that in these towns larger burners are used than are commonly employed here. I have heard it stated on good authority, that although Birmingham has little more than half the population of Glasgow, the total consumption of gas is as large as it is here. I may mention another striking fact, that the burners used for what is called common gas in London, Birmingham, and various other English towns, are provided with much wider openings than those used here; and that the burners are totally unsuitable

for burning our gas, producing with it a smoky flame, and giving comparatively little light. I have, for the purpose of shewing you practically the difference between our gas and such as is used in London, Birmingham, and most of the English towns, prepared a quantity of gas from common coal, equal to about 14 candles, and I shall burn it, and also the Glasgow gas, exactly at the rate of 5 cubic feet per hour, using identical meters and burners, so that the test may be strictly comparative. The result, I have no doubt, will convince you that our gas is very different, indeed, from that you have been accustomed to see in English towns, and I trust it may in some measure reconcile you to the paying of a price which, although much larger than we have been accustomed to, is moderate compared with other towns, when quality is taken into account. There is one English town which, I confess, fairly beats us in the economical production of gas, insomuch that they shew a larger surplus. I mean Manchester; but I understand that the reason for it is the larger price that is obtained for the coke produced in the gasworks of that town. However, that is a matter which I should scarcely touch upon. If the Glasgow corporation charge too much for their gas, there is no reason why I should undertake their defence, and that for two reasons—first, that they are well able to defend themselves; and, second, that my duty, as a public official, is simply to see that the Corporation keep up the quality to the standard required by the Act of Parliament.*

With regard to the prospects of an early reduction in the price of gas, I must ask you to allow me to make a short quotation from a recent number of the *Journal of Gas-lighting* (Feb. 10, 1874, p. 177), where, in discussing this subject, the editor makes the following remarks:—"In Scotland the effects of the rise in the

* The following table gives particulars regarding the population (including suburbs) of various towns, together with the number of meters in use, the gas rental, the value of coke, tar, &c., and the price of gas for the year ending 30th January, 1873.

	Glasgow.	Manchester.	Birmingham.	Liverpool.
Population, ...	560,000	500,000	350,000	550,000
Number of Meters in use, .	106,483	64,293	50,000	60,000
Gas Rental, ...	£252,619	£267,636	£236,753	£277,727
Coke, Tar, Amm. Liquor, and Meter Rents, . .	£32,000	£63,782	£182,019	£89,700
Price of Gas, ...	4/	3/6 and 3/9	2/3 to 2/7	3/6 and 5/9
Illuminating Power, Candles,	27	20	15	20

price of cannel are much more apparent. The names of 222 undertakings appear on our list, and it will be seen that of these, 66, or nearly one-third, raised the price of gas in the course of last year. We must remark here again that the advances were numerous in Scotland in the previous year, and thus the advances in Scotland are greater in number than in England and Wales. No considerable fall, if any, in the cost of cannel coal is to be expected, and the Scottish companies will inevitably, sooner or later, have to consider whether or not it will be possible to continue an exclusively cannel supply. In the meantime they are unquestionably promoting the rapid exhaustion of a material limited in quantity, and which, so far as we can see, cannot be replaced; which is highly valuable as an auxiliary, but the exclusive use of which is undeniably wasteful." Further on, the same writer states that in England and Wales advances in the price of gas are most numerous in coal districts. This apparent anomally is easily explained by the simple fact that, in districts far removed from the coal-fields, coke increases in value in a much higher ratio than it does in the coal-producing districts. And, again, as regards the Scottish gasworks, the coke produced from cannel coal is very inferior in quality, as compared with that made from English caking coal, and the increase in price of the coke is trifling, and does little to compensate for the rise in the value of coal.

But it cannot be doubted that a supply of gas of comparatively high illuminating power is a most desirable thing, independent altogether of the consideration of cost. Cannel gas gives very little more carbonic acid and other products of combustion than common gas, while it yields, in ordinary practice, twice as much light. In other words, if we wish in an apartment a certain amount of light, we must vitiate the air to nearly double the extent if we employ common gas, such as that used in Birmingham and London, that we require to do with Glasgow or other cannel gas, with a corresponding increase of temperature. As regards sulphur, it is even worse; for in common gas the average is about 30 grains per 100 cubic feet, while with our gas it certainly does not exceed 15 grains; so that, for equal quantities of light, about four times as much sulphurous acid is produced in burning common gas as compared with cannel gas. This is a very serious evil, and accounts, to a large extent, for the comparatively limited use of gas in the better class of houses in London and other English towns. Then, again, all our gas fittings are adapted for cannel gas, and are often deficient even for it; and a change to gas made from common coal

would necessitate a complete revolution in gas-fitting arrangements. I think you will agree with me, therefore, that we should retain our cannel gas as long as we can; and my own impression is, that by a judicious use of a mixture of splint or caking coal with oil shales, together with a limited use of cannel coal, a supply of gas of 25 to 28 candles may be kept up for very many years. Many of our splint coals give a gas of 18 to 20 candles, while the shales used in the manufacture of oil give gas of 30 to 45 candles. The oil trade is at present much restricted, and shale of good quality may be obtained in any quantity at a moderate price. The coke of oil shale is almost worthless, but, on the other hand, that of splint coal is very superior to that made from ordinary cannel coal.

I have said that the quality of the Glasgow gas is guaranteed to be 25 candles, and is in practice from 26 to 28—that is, as tested by the burner and in the manner described in the Glasgow Gas Act, 1869; but when consumed in smaller burners and at higher pressure, the result is exceedingly different; and I have reason to believe that the average illuminating power does not practically exceed 16 candles. We have here a loss of light that might be obtained by burners of proper construction and favourable circumstances as regards pressure, to the extent of about 40 per cent.; and if we calculate this upon the whole quantity of gas consumed in Glasgow, we find it to represent a money value, at 5s. per 1,000 feet, of about £130,000 per annum.

I admit freely and at once that it is impracticable, not to say impossible, to obtain in the every-day practice of common life results as good as those got by means of appliances the most perfect for developing the full photogenic value of the gas; but still a very great deal might be done to decrease the reckless waste of light that is constantly going on. I have no hesitation in stating that, without difficulty, from 20 to 23-candle power might be obtained in every-day life from 26-candle gas. We are in a similar position with regard to various forces employed for practical purposes. It is easy to calculate what power, represented by a given weight lifted a foot, ought to be obtained from a given quantity of water operating upon a water wheel; but the practical result always falls far short of the theoretical quantity. Again, the force obtained by the combustion of one pound of coal in the boiler of a steam engine is greatly less than the calculated figure. Still, mechanicians and mathematicians struggle on to obtain better results; and we have in some of the most recent forms of turbines an immense improvement on the water-wheels formerly in common use, while in the

steam engine we have in the best kinds of compound engines an approach to theoretical performance which was formerly deemed impossible of attainment. These improvements represent money saved; and it is equally the case with gas, but with this addition, that a decreased consumption of gas, with the same amount of light, would give increased healthfulness to our dwellings, where the products of the combustion of gas are an evil of no small magnitude. Here, again, we who burn cannel gas have an immense advantage over those who consume gas from common coal; for the loss of light in their case is even greater than ours, and is probably not usually less than 50 per cent. The object I have in view to-night is to place before you the theoretical considerations connected with the combustion of gas, and to give a few hints as to the means of burning it to the greatest advantage.

When a white porcelain slab is placed over a gas flame, a deposit of fine particles of carbon occurs: these particles exist in the flame, and the contact of the cold slab causes their instant deposition. A similar effect is produced by a current of cold air impinging upon the flame, a portion of which is thus cooled down below the point of ignition of the carbon, and the flame thus exposed to the draught smokes—that is, the finely divided particles of carbon pass into the air unconsumed. In ordinary circumstances the carbon is consumed in the upper part of the flame; and if the jet is a good one, and the pressure of the gas sufficient, no smoke is produced. In the Bunsen burner the gas is mixed with air sufficient to prevent the separation of the particles of carbon, and hence we have a flame practically valueless as a source of light, but convenient for the application of the heat of combustion to chemical vessels. The carbonaceous particles are formed in the flame by the action of the heat of the lower part of the flame, and the same thing occurs if the gas is passed slowly through a tube heated to redness, and in the retorts in gasworks a deposit of carbon is formed, which often increases to 3 or 4 inches in thickness. The source of the light in ordinary flames is the solid carbon, from the particles of which the light is radiated. Professor Frankland has shewn us that the light is not entirely due to this source; but for all practical purposes we may omit all other considerations. Now, the whole science of gas-lighting depends upon the burning of the gas in such a manner that the formation of the carbonaceous or sooty particles is fully developed, and at the same time fully consumed—in other words, to give a bright flame without smoke. It was, until within the last few years, an accepted axiom that economy in gas lighting could

only be obtained by the use of large burners, and that in small jets the contact of air with the flame was such as to ensure a too perfect and rapid combustion of the sooty particles—thus giving a flame with, considering the quantity of gas consumed, comparatively little light. Thus, to quote from a carefully compiled table of results, 2 feet of gas burned in a small jet (No. 0 union) gave a light of 3·55 candles, or for 5 cubic feet per hour, 8·9 candles—the pressure required in order to consume the quantity of gas with this small burner being 2 inches. But the same quantity of the same gas in No. 1 burner, at 1·3-inch pressure, gave 7·6 candles, or for 5 cubic feet, 19 candles. No. 2 burner, at ·66-inch pressure, gave 11 candles, or for 5 cubic feet, 27·5; and No. 3 burner, at ·45 pressure, gave 12·5 candles, or for 5 cubic feet 31·25.

2 cubic feet of gas, at—

2·0	inches pressure,	No.	0	fish-tail gave	3·55	candles,	or for 5 c. ft.	8·9
1·3	,,	,,	1	,,	7·6	,,	,,	19
·66	,,	,,	2	,,	11	,,	,,	27·5
·45	,,	,,	3	,,	12·5	,,	,,	31·25

These instructive figures I have selected from a valuable table of results obtained by Mr. Stewart of the Greenock Gasworks. It shews, apparently, that the larger the burner the greater is the illuminating power of a given quantity of gas; but it shews, also, what is equally important, that the lower the pressure the better is the result. By forcing gas through a small opening, the contact of the oxygen of the air becomes so intimate that an immediate combustion of the carbonaceous particles takes place almost at the moment of formation; but if allowed to escape gently, a much better result is obtained. I could give you many illustrations of this, but shall take just two from Mr. Stewart's table. The smallest, or No. 0 burner, which gave such a remarkably low result, gave, with a consumption of 1·5 cubic foot per hour, a light of 4·34 candles, or for 5 cubic feet, 14·25; and again, the No. 3 jet, which gave such a very high result at low pressure, gave, with a consumption of 5 cubic feet per hour, which required a pressure of 1·7 inch, only 22·5 candles, or little more than $\frac{2}{3}$ of the power obtained at a pressure of ·45 inch and consumption of 2 cubic feet per hour. Now, recent investigations have clearly shewn that very fair values may be obtained even with very small burners, provided always the pressure is reduced sufficiently low to allow the gas to pass gently into the air. This reduction of the pressure may be effected in two ways—1st, the gas may be reduced in velocity by means of a governor or regulator

placed at some distance from the point of ignition; or 2nd, it may be effected by contracting the lower part of the burner, or checking the flow of gas through the burner, by stuffing it with cotton-wool, cloth, or iron filings, or obstructing it in some other way. All the patent gas-burners recently introduced are constructed upon this principle—all they do is simply to pass the gas into the air at a low pressure.

Let us now examine some of the forms of gas jets, and let us take first the original burner, the familiar rat's-tail or cockspur jet, which, in Glasgow, is commonly used in street lamps and stair lights. It is made of cast-iron, bored as wide as possible throughout, leaving a thin shell at the top, which is then pierced with a fine orifice. I have tested two sizes of these burners at various pressures, and the experiments shew that, under any circumstances, it is impossible to obtain a high result. The gas used, when tested in the usual manner, gave a light equal to 29·24 candles. The smaller burner had an opening of $\frac{1}{48}$ of an inch, and the larger one an opening of $\frac{1}{32}$ of an inch. The results were these—

BURNER.	PRESSURE.	LENGTH OF FLAME.	GAS PER HOUR.	ILL. POWER.	ILL. P. PER 5 C. FT.
No. 1	·5 inch	2 inches	·45 c. ft.	1 candle	11·1 candles
,, 1	1 ,,	$3\frac{1}{2}$,,	·60 ,,	1·9 ,,	15·8 ,,
,, 1	1·5 ,,	$4\frac{3}{8}$,,	·90 ,,	2·7 ,,	16·6 ,,
,, 2	·5 ,,	$3\frac{7}{8}$,,	·80 ,,	2·8 ,,	17·5 ,,
,, 2	1 ,,	$5\frac{7}{8}$,,	1·13 ,,	4 ,,	17·7 ,,
,, 2	1·5 ,,	$7\frac{1}{2}$,,	1·45 ,,	5·1 ,,	17·6 ,,

It thus appears that with No. 1, which is, I understand, used for stair lights, at $\frac{1}{2}$-inch pressure, not much more than $\frac{1}{3}$ of the light the gas is capable of yielding, when properly burned, is obtained; and in no case more than about 57 per cent. The No. 2 jet is somewhat better, giving uniformly about 60 per cent. of the real value of the gas.

When two rat-tail jets are held at about a right angle to one another, the lights coalesce and form a flat sheet of flame. When this discovery was first made, two burners were fitted up in this way; but soon a single burner was contrived which combined the two, and hence was called, and is still called, a union jet, or sometimes, a fish-tail. It is simply a short cylindrical tube with a flat top and with two orifices, drilled at about 90° to one another, and meeting in the centre. The construction will be readily understood from the sketch suspended on the wall. A great improvement has been obtained by cutting off the metal top and substituting one of porcelain or earthenware, the advantages obtained being that the body of the burner does not heat, and particularly that the

orifices remain constant in size, while those of iron gradually rust up, and in order to give a satisfactory light require to be occasionally cleaned. In some cases, the entire burner is constructed of earthenware, or, as it is called, lava; but I do not like these jets, as, when fixed in by means of white lead, they cannot be removed without breaking them.

Several kinds of union burners, with obstructions to reduce the pressure, have been introduced. Leoni's jet is partly brass and partly iron, with an "adamas" or porcelain tip, and the obstruction consists of a thin web of cotton wool inserted above the iron part of the jet. This is a very good burner, but rather clumsy in appearance. Another, and, as I think, a better kind, is that called Bray's regulator. This has a brass body of the ordinary size, and the obstruction consists of a double layer of cotton cloth stretched over a brass ring. As I consider these the best union burners obtainable at moderate cost, I have selected them for a series of experiments, to which I shall briefly refer. Nine sizes of jets were tested, and each was tried at three different pressures—½-inch, 1-inch, and 1½-inch. These tests were made on three different days, during which the gas varied slightly in illuminating power: during the ½-inch trials, it was 27·72 candles; during the 1-inch trials, it was 29·05; and during the 1½-inch tests, it was 28·61, the average being 28·46, or say 28½ candles. The results obtained are represented in this table:—

UNION JETS (BRAY'S REGULATORS).

Burner No.	At ½-inch Pressure.			At 1-inch Pressure.			At 1½-inch Pressure.		
	Gas.	Ill. Power.	Calculated to 5 C. Ft.	Gas.	Ill. Power.	5 C. Ft.	Gas.	Ill. Power.	5 C. Ft.
0	1	2·9	14·5	1·5	3·5	11·7	2	3·5	8·8
1	1·15	4	17·4	1·8	4·8	13·3	2·45	4·8	9·8
2	1·5	6	20·	2·3	8·1	17·6	3	8·3	13·9
3	1·8	8·5	23·6	2·75	11·3	20·6	3·55	12·4	17·5
4	2·4	12	25	3·6	17	23·6	4·3	16·7	19·4
5	2·6	13·6	26·15	4·35	22·8	26·2	5·1	24·2	23·7
6	3·15	17	27	4·95	28·4	28·7	5·8	30	25·9
7	3·8	21·4	28·16	6·05	36·6	30·2	...	gas blows	...
8	4·7	26·4	28·08	7·1	45·4	32	...	gas blows	...

These experiments bring out very strikingly the fact that gas burned in small jets can only be made to give a fair amount of light when the pressure is low. No. 4 jet, at ½-inch pressure, burns 2·4 cubic feet per hour, and the light, calculated to 5 feet per hour, is 25 candles; at 1-inch pressure, No. 2 jet burns 2·3 cubic feet per hour, and the light, calculated to 5 feet, equals 17·6 candles; at 1½-inch pressure, No. 1 jet consumes 2·45 cubic feet per hour, and the light, calculated to 5 feet per hour, is equal to 9·8 candles. Five cubic feet of gas, therefore—

At ½-inch	pressure,	gives the light of	25	standard sperm candles.
,, 1	,,	,,	17·6	,,
,, 1½	,,	,,	9·8	,,

Another very good description of union jet is that known as Morley's patent. This is a brass burner of rather clumsy shape, with "adamas" tip, and at the bottom one or two small holes of about the same area as the holes in the top of the jet. Then there is Williamson's jet, of nearly the same shape externally as Morley's, but unnecessarily complicated in the mode of reducing the pressure. Da Costa's burner is a large hollow vase, stuffed with iron turnings; and there are many others, but they are all expensive, and their performance is no better than that of Bray's burner, which is retailed at 2d. each. And here I would remark, that none of these burners *regulate* the flow of gas, they only *obstruct* it; but even this is a useful result, when the pressure in the main is, as it almost invariably is, too high for the economical combustion of gas—not the least important effect being the prevention of "hissing," which is often an intolerable nuisance. But when the supply of gas is defective, from the pipes being too narrow or in some way obstructed, the use of any of these stuffed burners does harm rather than good.

Another method of breaking the pressure is, by placing a thin piece of platinum across a union jet. This is the principle patented by Mr. Scholl of London; and the effects of his burner upon the light given by the common gas of London have been very highly spoken of by Dr. Letheby, Professor Frankland, and other eminent authorities. More recently, Mr. Scholl has introduced a burner similarly constructed, for burning cannel gas; but I find that it is better adapted for English cannel gas (20 to 23 candles), than for that made in the Scotch gasworks.

After the rat-tail burner had been in use for some time, a modification of it, with three orifices instead of one, was introduced, and

this was called a cockspur jet; and another was subsequently invented, in which a series of very fine holes was placed across the top of the burner, giving a practically flat flame, which was called a bat's-wing. This system was soon supplanted by a slit, which was found to answer the purpose equally well, if not better; and our present bat's-wing burner is simply a cast-iron tube, having a top with a strait slit cut in it. This jet is also made in earthenware and in steatite—a magnesium silicate which is indestructible by heat, and is easily turned and cut. The bat-wing jet is particularly adapted for large-sized burners, consuming from 3 to 5 feet per hour, and it requires an even lower pressure than the union or fish-tail jet in order to burn the gas with the greatest economy. With a pressure of 3½ to 4-tenths of an inch, a bat-wing consuming 5 cubic feet per hour may be made to give, at least, as good a result as the best fish-tail jets; and the standard burner used for testing the cannel gas (20 to 23 candles) in London and some other places in England, is a steatite bat-wing of this kind. With gas of 26 to 30 candles, the union burner described in the Glasgow and Dublin Gas Acts, gives equally good results; but with gas from 20 to 25 candles, the bat-wing indicates a sensibly higher illuminating power.

The great loss of light experienced when gas is consumed in bat-wing burners at any but comparatively low pressures, has given rise to many efforts to combine with the jet an apparatus to reduce the pressure of the gas, which in the gas mains usually ranges from 1 to 2 inches, and is sometimes even higher. Various bat-wing burners having obstructions, as in the case of the union jets already described, have been constructed, but perhaps the best of them is Brönner's. This is a rather wide brass cylinder tapered at the bottom, and having at the top a short steatite burner which screws in. At the lower or contracted end a piece of steatite is inserted, in which is an oblong slot. The gas has to force its way through this slot, which has a smaller area than that of the slit at the top, and it expands into the brass cylinder and escapes through the slit at a pressure of from 2 to 5-tenths of an inch. The rate of consumption is therefore dependent on three conditions:—1st, the area of the opening at the bottom; 2nd, the area of the slit of the burner; and 3rd, the initial pressure of the gas. There are two kinds of Brönner's burners, intended respectively for common and cannel gas—the former having much larger openings at the top than the latter. Those for common gas are very much used in London, and are exceedingly effective; but they are of no use

BRÖNNER'S BURNERS.

At 1-inch Pressure.					At 1½-inch Pressure.				
Burner No.	Top No.	Cubic Feet per Hour.	Illuminating Power.	Calculated to 5 C. Ft.	Burner No.	Top No.	Cubic Feet per Hour.	Illuminating Power.	Calculated to 5 C. Ft.
2	2	1·2	6	25	2	2	1·4	5·7	20·4
2	3	1·4	7·2	25·7	2	3	1·95	8	20·5
2	4	...	smokes.	...	2	4	2·3	11·2	24·3
2	5	...	,,	...	2	5	2·4	12·2	25·5
2	6	...	,,	...	2	6	...	smokes.	...
2½	2	1·4	5·5	19·6	2½	2	1·9	9	23·7
2½	3	1·7	9·2	27	2½	3	2·3	11	23·9
2½	4	2·03	11·2	27·6	2½	4	2·7	13·1	24·3
2½	5	...	smokes.	...	2½	5	2·85	15·5	27·2
2½	6	...	,,	...	2½	6	3	16·5	27·5
3	2	1·45	6·8	23·4	3	2	2	9·2	23
3	3	1·90	9·4	24·7	3	3	2·4	12·3	25·6
3	4	2·13	12·2	28·7	3	4	2·8	16·1	28·7
3	5	...	smokes.	...	3	5	3·15	18·7	29·7
3	6	...	,,	...	3	6	3·25	19·6	30·2
3½	2	1·5	6·3	21	3½	2	2·12	9·6	22·9
3½	3	1·95	9·0	23·1	3½	3	2·55	13·7	27·2
3½	4	2·55	13·1	25·7	3½	4	3	15·7	27·6
3½	5	2·80	15·6	27·9	3½	5	3·5	19·6	28·6
3½	6	3·0	16·9	28·2	3½	6	3·6	21·1	29·9
4	2	1·6	6·9	21·6	4	2	2·3	10·6	23
4	3	2·1	11·6	27·6	4	3	2·9	15	25·9
4	4	2·65	14·5	27·4	4	4	3·3	18·5	28
4	5	3·45	19·1	27·6	4	5	4·1	23·4	28·5
4	6	3·55	19·6	27·6	4	6	4·2	24·3	28·9
5	2	1·77	8	22·6	5	2	2·6	10·5	20·2
5	3	2.3	12·9	28	5	3	3·3	14·8	22·4
5	4	3·3	16·7	25·3	5	4	4	21·6	27
5	5	4·1	22·5	27·4	5	5	5	27·5	26·8
5	6	4·3	24·6	28·6	5	6	5·3	30	28·3

whatever for Glasgow or other cannel gas. There are six sizes of Brönner's burners for cannel gas, the difference being entirely in the area of the rectangular slot at the bottom, and there are five sizes of steatite tops, so that we have no fewer than thirty combinations, thus affording a most extensive range of selection to suit any description of gas or any standard of pressure. Of the thirty combinations, however, I have found six to be unsuitable for our gas when the pressure is low (1 inch), but only one at a pressure of an inch and a half. The photometric results are contained in the preceding table. The gas used, tested as usual, was of 28·2 candles.

The average of the tests at 1-inch pressure is 25·7 candles, and of those at 1½-inch pressure, 25·8 candles.

The advantage as compared with seven sizes of ordinary bat-wing burners at the same pressure, is about 20 per cent.; and, as compared with seven sizes of union jets, 15 per cent., but the difference is greatest in the smaller sizes. In eight cases at 1½-inch, and one at 1 inch, the results were superior to those obtained by the standard union jet. There are several burners of a shape similar to that of Brönner, in which the opening below is capable of adjustment by a screw. Two of these are figured in the accompanying sketch of gas burners.

Another way of improving the light of gas of low quality, where bat-wings are used, is to use a double-slit burner. If two bat-wing flames are brought together, especially if the slits of the burners are narrow, and the pressure rather high, the sum of the two lights when joined is very considerably in excess of the same jets when separate, and the difference is usually so great as to be apparent to the eye without requiring the aid of a photometer. But with flames burning at reduced pressure, as in Brönner's burners, especially if the gas is of high quality, the result of joining the two jets is to diminish rather than increase the light, with the production of much smoke.

There is just another bat-wing that I wish to mention, although it is not one that is of any use for such gas as we burn in Glasgow, but it is so valuable for common gas and particularly for air-gas, which is used to some extent in the United States and Canada, that I cannot omit to shew it. It is called the regulating burner, and was patented in the United States in 1871, and it consists of a very much elongated bat-wing, with rather narrow slit, surrounded by a brass tube, into which a portion of the gas (the amount being regulated by a small screw) escapes and burns around the bat-wing,

the force of the gas issuing from the narrow slit giving direction to that burning at the top of the brass tube, spreading out the whole to a fine soft flame.

I do not propose, on the present occasion, to take up the subject of Argand burners,—first, because our time will not allow me to describe the improvements recently introduced intelligibly; secondly, because the subject has been fully discussed by Mr. Kirkham and Mr. Sugg, of London, and the results published; and thirdly, because our cannel gas cannot be burned profitably or conveniently in Argand burners, their use being entirely confined to the combustion of gas of low quality—say from 12 to 18 candles. I have here various forms of Argands, the improvements over the older forms of the Argand consisting of means of preventing too strong a draught in the chimney, and of preventing the escape of the gas at too high a pressure. Sugg's London Argand, which is now generally used in England for testing gas made from common coal, accomplishes these ends in a way that leaves little hope of any further improvement being effected; and the adoption by the English gas examiners of this burner has raised the standard of common gas at least 2 candles, that is, from 14 to 16 candles.

Before leaving the subject of burners, allow me to say that it is of very great consequence that these should fit closely, for a slight escape of gas at the base of the burner causes a very considerable loss of light, besides producing usually a most disagreeable and unwholesome odour. All burners should be fixed with white lead; when this cannot be had, a little yellow soap scraped off from a cake recently used may be employed as a temporary expedient.

Now, as I have already hinted, the effect of reducing the pressure in gas burners is only a partial cure for the evil it is intended to remedy; for the pressure in the mains is variable at different periods of the day, and is influenced by many accidental circumstances, and may vary at any given place from an inch or even less to two inches or even more. The consumption of gas by any given burner, whether stuffed or otherwise, may therefore be double at one time what it is at another; and, whether as a matter of economy or of comfort, it is most desirable that we should have the means of protecting ourselves from the effect of changes of pressure in the mains. For a great many years gas engineers and other experts in the science of gas-lighting, have recognised this as the great desideratum of gas illumination, and many regulators have been introduced and patented, in some of which mercury was employed as the regulating medium. But most of these have

had some defect which has caused their use to be discontinued, and many of them are too expensive for general use. A few years ago a simple form of gas regulator for street lamps was introduced, I do not know by whom, and various forms of it and improvements on it have been made by Mr. Sugg and many other practical gas engineers. Of all the modifications of the instrument, the best, in my opinion, is that of Mr. D. Bruce Peebles of Edinburgh; in fact, his lamp regulators are so superior that they are likely to supplant all others. Already about 9,000 of these have been applied to the street lamps in Glasgow, and I understand that it is the intention of the authorities to introduce them all over the town—the saving thereby effected I calculate to be about £6,000 per annum, without any diminution of light. The construction of the regulator will be readily understood by examining the instrument, and from the drawing upon the wall. The principle is a simple one—the action of the pressure of the gas on a diaphragm of leather, or other flexible membrane, carrying a brass ball or cone placed within a socket, so that the greater the pressure of the gas, the smaller becomes the space between the cone and socket. By means of weights the instrument can be adjusted to work at any desired pressure, and the lamp regulators are usually set at ·5 inch; and one of the great advantages of Mr. Peebles' apparatus over all others is, that it can be regulated while the gas is burning. Formerly leather, such as is used for the drums of dry meters, was the substance used for the diaphragm; but Mr. Peebles has also used bladder-skin, soaked in glycerine, which is found to answer the purpose admirably, provided the regulator is placed outside the glass globe or lantern, so as not to become heated. Regulators of a larger size, suitable for dwelling houses, workshops, public halls, and churches, are now constructed, and are likely to come into general use. I have had one attached to the meter in my own house for about two years and a half, and I can speak of its performance with the highest praise. It is set at ·9 pressure, as I use obstructed burners, some of Brönner's, but mostly Bray's; but with common unstuffed burners it should be set lower, say ·6 or ·8. In my own case I have not found the pressure on the gas throughout the house to vary sensibly, whether only 5 or 6, or upwards of 20 burners are lighted; and the instrument appears to accommodate itself almost instantly to any variation in the pressure on the mains outside the house. In churches and public halls the audiences are frequently annoyed by the jets suddenly flaring up and hissing, owing to some change in the pressure in the mains. Not only would such un-

had some defect which has caused their use to be discontinued, and many of them are too expensive for general use. A few years ago a simple form of gas regulator for street lamps was introduced, I do not know by whom, and various forms of it and improvements on it have been made by Mr. Sugg and many other practical gas engineers. Of all the modifications of the instrument, the best, in my opinion, is that of Mr. D. Bruce Peebles of Edinburgh; in fact, his lamp regulators are so superior that they are likely to supplant all others. Already about 9,000 of these have been applied to the street lamps in Glasgow, and I understand that it is the intention of the authorities to introduce them all over the town—the saving thereby effected I calculate to be about £6,000 per annum, without any diminution of light. The construction of the regulator will be readily understood by examining the instrument, and from the drawing upon the wall. The principle is a simple one—the action of the pressure of the gas on a diaphragm of leather, or other flexible membrane, carrying a brass ball or cone placed within a socket, so that the greater the pressure of the gas, the smaller becomes the space between the cone and socket. By means of weights the instrument can be adjusted to work at any desired pressure, and the lamp regulators are usually set at ·5 inch; and one of the great advantages of Mr. Peebles' apparatus over all others is, that it can be regulated while the gas is burning. Formerly leather, such as is used for the drums of dry meters, was the substance used for the diaphragm; but Mr. Peebles has also used bladder-skin, soaked in glycerine, which is found to answer the purpose admirably, provided the regulator is placed outside the glass globe or lantern, so as not to become heated. Regulators of a larger size, suitable for dwelling houses, workshops, public halls, and churches, are now constructed, and are likely to come into general use. I have had one attached to the meter in my own house for about two years and a half, and I can speak of its performance with the highest praise. It is set at ·9 pressure, as I use obstructed burners, some of Brönner's, but mostly Bray's; but with common unstuffed burners it should be set lower, say ·6 or ·8. In my own case I have not found the pressure on the gas throughout the house to vary sensibly, whether only 5 or 6, or upwards of 20 burners are lighted; and the instrument appears to accommodate itself almost instantly to any variation in the pressure on the mains outside the house. In churches and public halls the audiences are frequently annoyed by the jets suddenly flaring up and hissing, owing to some change in the pressure in the mains. Not only would such un-

pleasant occurrences be prevented, but a saving of at least a third of the gas consumed would be effected by the use of a regulator. In mills and other public works, a regulator should be placed in each flat of the building; but for houses, churches, and halls, it is sufficient to attach a single instrument to the outlet of the meter. By the kindness of Mr. Peebles, of the Fountainbridge Meter Works, Edinburgh, I am enabled to exhibit various specimens of regulators, suited to private houses, and to churches and public works.

I must here notice an invention of Mr. Sugg of London, in which a very small-sized regulator is placed immediately below the burner for domestic use. These regulators differ from those employed for lamps, in so far as the upper side of the diaphragm is not exposed to the air, and I find that they are not really regulators, as they only check the flame of the gas. A good street lamp regulator will pass the same quantity of gas within about 10 per cent., no matter what the pressure is, but those of Mr. Sugg intended for dwelling houses do not give such satisfactory results. I have had an opportunity of testing several of these fitted with bat-wing burners, and find them to give very nearly the following rates of consumption:—

At	·5-inch	pressure	2	cubic feet	per hour.
,,	1	,,	3	,,	,,
,,	1·5	,,	4	,,	,,

The performance of this apparatus, therefore, is not superior to that of the obstructed burners of which I have spoken.

In all the remarks I have made hitherto I have spoken only of naked flames, and undoubtedly, if we wish to economise the light of gas jets, we should use them without globes or other glass vessels, which not only absorb a large proportion of the light, but very often are of such a shape that they produce a current which seriously diminishes the light of the flame itself. I find that a piece of ordinary transparent glass held in front of a flame absorbs about 10 per cent. of the light, and the loss with a transparent globe, if its size and shape are properly proportioned, is not sensibly greater. Frosted globes absorb about 25 per cent. of the light, but the character of the illumination is improved, the light being diffused, and so rendered less trying to the eye. On the same principle large globes are better than small ones, so far as the eye is concerned; but the use of them is a luxury that must be paid for in the shape of a large extra expenditure of gas in order to obtain an equal amount of light. I have made experiments with three sizes

of moons, as they are called—that is, globes frosted all over, the diameters being 6 inches, 7½ inches, and 10 inches, and I find that the loss of light is

With the 6-inch	globe	25	per cent.
„ 7½	„	27½	„
„ 10	„	38	„

The size of the lower opening in all the globes was 2 inches, and that of the top was from 4 to 5 inches. In Brönner's system the globes are much opener below, thus preventing the draught from impinging forcibly upon the flame, and the top is also very open, the height being only about three-fourths of the diameter. This is an excellent shape, but I have not yet had an opportunity of testing a moon of this kind photometrically. I have tried what is called a carnelian globe, however, of this shape, and find the loss to be 37 per cent., which is certainly moderate, considering that the material is not transparent but only translucent. The best of shades, probably, for rooms in which there are no disturbing currents of air, are shallow or saucer-shaped glasses frosted all over; but in many apartments they cannot be used in consequence of the flame being blown about by currents. In shallow shades a large proportion of the light is reflected from the surface of the glass up to the ceiling, and if this is pure white, as it ought invariably to be, the light is thrown down upon the table and diffused through the room. The loss of light with globes has long been recognised, and various kinds of tops have been proposed in order to modify the current. I find that these, to be of any service, must be brought very close to the globe, being in 6-inch globes barely ¼ inch, and in 10-inch globes only ⅛ of an inch from the rim to obtain the very best effect. The saving is very considerable. In the case of the 7½-inch frosted globe the loss of light was 27½ per cent., but when a mica cover was nicely adjusted to it the loss was only 12 per cent. With the 10-inch globe also a saving of 9 per cent. was effected by a mica cover—that is, the loss of light was reduced from 38 to 29 per cent.

It is of great consequence that the light should be placed as near as possible to the point where it is required. The whole science of photometry depends upon the fact that the intensity of light decreases as the squares of the distances. Thus a light which covers a space of 1 square foot, say at 1 yard distance, will cover 4 square feet at 2 yards, 9 square feet at 3 yards, and 16 square feet at 4 yards; and as the light, which at 1 yard is concentrated upon a single

square foot, is at 4 yards diffused over 16 square feet, it follows that one square foot of the latter space is illuminated to the extent of just $\frac{1}{16}$ of the intensity at the latter distance that it was at the former. While, therefore, it is practically inconvenient to have a gas flame too close to the eye, it should not be too far removed. A very good reading distance is about 3 feet, and a gasalier should not be removed more than 3 or 4 feet from the table, or from 5 to 6 feet from the floor. In public buildings there is often a very great waste of gas by having the jets far removed from the place where the light is wanted, and sunlights are pre-eminent in this respect.

The painting of dining rooms and other apartments in dark wainscot and other depressing styles, is the cause of an enormous waste of gas, such rooms being excessively difficult to light up, owing to the almost total absence of reflection by the walls and ceiling. Perhaps the most difficult room to illuminate, and I have seen many of the sort, is one covered with a dark green or crimson flock paper, and having an oak-painted ceiling. The depressing influence of such a room upon the mind is even a greater evil than the waste of gas resulting from the almost futile endeavour to light it up.

In the case of public works the walls and ceiling should be kept as white as the occasional application of whitewash will make them; and when the lights are placed, as they frequently are, against the walls, they should have glass reflectors behind them. I have here two excellent forms of reflectors, which I have borrowed from Mr. M'Leod of Alston Street, one being a shallow concave mirror of pure silver deposited by the now well-known process, the other constructed of pieces of ordinary silvered glass.

I have left myself little time to speak of street illumination, although it is a very important part of my subject. A large proportion of the light of our public lamps is thrown away, allowed to pass up into the air and be lost, while in the centre between two lamps placed, say 50 feet apart, there is a space the almost total darkness of which is rendered only more conspicuous by the proximity of the lamps. The most successful, I may say the only successful, attempt to economise this lost light is that by Mr. Skelton, architect, of London, whose catoptric lamp, of which I have here a drawing, is a most ingenious and effective arrangement. Above the level of the flame, both in the sides and top of the lantern, are placed slips of silvered glass by which the light, that would otherwise be lost, is reflected upon the

ground at a considerable distance from the lamps, thus diminishing the darkness in the centre space I have spoken of. I have had an opportunity of practically testing these lamps, and I find that at a certain distance from the lamps the light is exactly doubled, and I understand that at a still greater distance the light is trebled, at least. There are two or more of these lamps in St. Vincent Place, and one on the Jamaica Street Bridge, at either of which places you can examine their performance for yourselves. The lamps are, of course, more expensive than the common kind, but the saving of light is so great that I calculate that the extra cost would be compensated for in a single year.

The lighting of bridges is of some interest to us in Glasgow, where we have so many fine erections spanning the river Clyde. The lamps upon these are invariably placed upon the parapet, so that at least one half of the available light is lost in the depths of the river. This is an evil which might be mitigated by placing the lamps at the side of the footpath, as in ordinary streets, or by making the lamp-posts on the parapet in the form of a bracket, so that the lantern will overhang the footpath.

And now, gentlemen, I must close my lecture with the hope that I have not wearied you with too much detail regarding a subject in which I naturally take a great interest, but which is probably much less interesting to you. And yet it is a matter of grave importance, not only as regards the immense sum of money thrown away upon gas rendered ineffective by improper means of burning it—a loss which in Glasgow alone I calculate to be equal to £130,000 per annum; but still more as regards our health and comfort, for a diminished consumption of gas would undoubtedly render our dwellings more comfortable and improve our health. I sincerely trust, therefore, that my remarks this evening will have some effect in checking the extravagant waste going on everywhere around us, and conducing to the general introduction of an improved system of burning gas.

Discussion on Dr. Wallace's Paper.

Mr. J. J. Coleman said—With reference to the figures which have been brought before the Society by Dr. Wallace, I may remark, in the first place, that he has shewn to us clearly the different effects produced by using different burners. I should

like to remark that in Birmingham, London, and other towns mentioned, the gas is tested by Argand burners, and I should like to ask Dr. Wallace whether the same burner has been used throughout the whole of these towns in reference to the figures, or whether he thinks the burners used in the different towns are such as to give the highest illuminating power. In the other part of Dr. Wallace's remarks I was rather surprised to hear that the oil trade was extinguished, and as I see several gentlemen connected with the trade in the room, I was surprised to see the cheerful way in which they took it. As a mere matter of fact, I think I can state that the largest concern of the kind in Scotland is now working to the full extent of its power. As a matter of fact, there is no evidence to prove that the trade will not recover as other trades have recovered.

Dr. WALLACE—Before any other gentleman speaks, I should like to reply to Mr. Coleman. I am glad to hear the oil trade is not defunct. What I meant is that in the meantime, and while a less quantity of shale is used for making oil, it may be used in making gas. Then, as regards the various towns of which I have spoken, there are three kinds of burners used in testing gas. The rule in testing gas is simply this—to use the burner that gives the best result. It is found that cannel gas burns best with the fish-tail or bat's-wing. In Glasgow and Dublin we are bound down to the union jet with certain conditions, but in some of the English towns they are bound down to use the bát's-wing jet. A bat's-wing gives a somewhat better result, with gas of 20 to 23 candles, and therefore is used in some of these towns. When we go further down than 20 candles, the use of the bat-wing or fish-tail is no longer admissible, we must then use the Argand; and Sugg's Argand is almost universally used now for testing gas of low quality. It is the best kind of Argand that has yet been constructed. The rule is, unless you are bound down by Act of Parliament, to use the burner that gives the best result.

Mr. MACKINTOSH—I am sure that all the gentlemen present must have been very much struck with the table shewing the contrast between the effect of the ½-inch pressure and the 1½-inch pressure. What strikes me as very extraordinary is that the higher the pressure, and the more gas going through the meter, the less light we get; and the less gas there is going through the meter, the more light we get.

Dr. Wallace—That is not. exactly the case. We use different burners, of course, to give a larger amount passed through. But these are the results calculated to five cubic feet per hour.

Mr. Mackintosh—With the higher pressure, is there more passed through and therefore paid for?

Dr. Wallace—Certainly.

Mr. Foulis said—This pressure that Dr. Wallace speaks of has nothing to do with the pressure of the gas as it passes from the meter. It is the pressure of the gas at the burner where it is being burned. If you have a burner passing 5 feet through it at ½-inch pressure, the burner must be larger in the aperture than if the pressue is 1½ inch. The pressure in the street mains must be kept up as nearly the same as possible, in order that there may be a full supply. I don't think I need add anything to what Dr. Wallace has said. There is no one who has given attention to this subject but must feet the enormous loss going on through the whole country from defective burners. It has received a great deal more attention in England than it ever did in Glasgow. In 1869 there was a report by the referees appointed under the City of London Act, and if you will allow me I will read one clause, which fully confirms all that Dr. Wallace has said. I don't think Dr. Wallace has referred to it.

Dr. Wallace—No.

Mr. Foulis—The report says:—"The referees adopted as their test-burner for common gas the one known as Sugg's Letheby burner, which had previously been in use at the testing station established by the Corporation of the City of London under the Act of 1860. Taking this burner as a temporary standard, the referees, on testing by the photometer the large number of burners which they had collected, found that the diversity as to illuminating power was surprisingly great, and such as will appear incredible to any one who has not ascertained the facts by careful experiments. They also found that the kinds of burners in common use are extremely defective, thereby entailing upon the public a heavy pecuniary loss as well as other disadvantages. In order to examine this important matter more fully, the referees, with the ready permission of the proprietors, inspected several large establishments in

the city, where, owing to the prevalence of night-work, an unusually large amount of gas was consumed. The inspection in every case confirmed the apprehensions which the referees had formed from their examination of the burners which they had procured from the leading gas-fitting establishments. In the offices of two of the daily newspapers (establishments which consume more gas than any others), they found that the burners principally in use gave out only 55 per cent. of light compared with the Sugg-Letheby burner, or with Leoni's Albert crutch burner, and yet the price of the last-named burner is almost identical with that of the very bad burners employed in those offices. Tested by the Bengel burner, or Sugg's new burner, the amount of light given by these imperfect burners is only between 47 and 49 per cent. of what is obtainable from the gas. From these facts, and from many others which the referees could specify, it appears that an enormous waste of gas prevails with a corresponding pecuniary loss to the public. In the case of the two newspaper offices above-mentioned, it appears that the burners chiefly used give out only one-half of the illuminating power of the gas supplied to them, and for which they pay. Nor is this pecuniary loss the only disadvantage; for, by the burning of more gas than is really needed, an unnecessary amount of heat is generated, and the atmosphere deteriorated, rendering the condition of the workmen not only less comfortable, but also less healthy than it otherwise would be! The referees think it a matter of urgent importance that such facts should be brought to the knowledge of the public. With one or two exceptions, the manufacturers of gas apparatus are wholly ignorant of the principles which regulate the development of light from gas, and the consequence is that the market is filled with bad burners instead of good ones, which might be had as cheaply."

Mr. W. R. W. SMITH—So far as Dr. Wallace's investigations have gone, what is the best burner?

Dr. WALLACE—I think the best burner we can use is this one of Brönner; Bray's jets are certainly very far superior to the iron jets in use.

Mr. JAS. R. NAPIER—I suppose Dr. Wallace means that the steatite tip does not add anything to the light, but simply makes the burner more enduring.

Dr. WALLACE—Just so.

Mr. Jas. R. Napier said he did not think that Brönner's burners possessed any advantage whatever over an old-fashioned iron burner, with a round hole in the lower part. Mr. Bartholemew, the former gas manager of the city, had supplied him with a number of this construction, many years ago, which he still uses—they are $1\frac{3}{4}$ inches long. Brönner's oblong slit at the lower part is clearly a difference without a benefit. The title of Dr. Wallace's paper being the "Economical Combustion of Gas," he supposed that the subject would be continued in reference to the *heating* effects of combustion; if not he would inquire as to the possibility of getting cheaper gas—for heating purposes; of converting *all* the coal into gas at the pits, according to Dr. Siemen's suggestion; and supplying an easily managed gaseous fuel at much less cost than solid coal.

Mr. Mayer at this point suggested that the discussion should be adjourned till another evening, as the hour was late; but it was found that there was no other evening of the session unoccupied, and the subject was dropped.

It was subsequently arranged that the subject would be discussed at next meeting of the Sanitary and Social Economy Section.

VI.—*On the Cubic Space and on the Volume of Air Necessary for Ensuring the Salubrity of Inhabited Places.* By MR. JAS. R. NAPIER, F.R.S.

[Read before the Society, April 1, 1874.]

MY attention has been directed to a note by General Morin, with the above title, in the *Comptes Rendus de l'Academie des Sciences* for 4th August, 1873, the results of which are apparently at variance with some remarks of mine in a paper on "The Economy of Fuel in Domestic Arrangements."

General Morin, after crediting the origin of his investigation to Dr. De Chaumont, proposes the following question for solution:—"What is the volume of air which it is necessary to introduce into an inhabited place, per individual, in order to maintain it in a state of salubrity sufficiently near to that of the external air?" And gives the following, as he says, necessarily approximate solution:—

$$x = \frac{m - E\left(\frac{1}{n'} - \frac{1}{n}\right)}{\frac{1}{n'} - \frac{1}{n}} \quad \text{..........................A.}$$

in which E is the cubic space occupied per individual.

x, the volume of air to extract and to introduce per hour and per individual, in order that the proportion of vitiated air or of carbonic acid should not exceed a value $\frac{1}{n'}$ determined by observation.

m, the volume of gas and of vapours hurtful to health exhaled per hour and per individual.

$\frac{1}{n}$ the mean normal proportion of carbonic acid in air which we regard as pure.

The formula, which is derived from the statement,

$$\text{“}\frac{1}{n} E + m + \frac{1}{n} x - \frac{1}{n'} x = \frac{1}{n'} E,\text{”}$$

shews, he says, "That the more the volume of inhabited places increases, the more that of the air to be renewed, in order to maintain a determined degree of salubrity, diminishes; but that it

increases inversely as the cubic space occupied by each person is less." This is evident within certain limits, if the formula itself is correct; but I submit that there is a fallacy in it.

If the volume of the space occupied by the individual is to be admitted in the estimate, the time during which the space is occupied must necessarily be an element in the statement.

The formula as it stands, merely shews the quantity of air which it is necessary to introduce and extract in one hour, in order that at the expiry of that hour the space shall be at the predetermined state of vitiation. For more than one hour's occupation the formula, with the deductions quoted above and the examples given in the *Comptes Rendus*, are erroneous.

If it is important that the volume of the space occupied by the individual should be considered in the calculation, I submit the following as a truer solution of the question:—

$$x = \frac{m - \frac{E}{y}\left(\frac{1}{n'} - \frac{1}{n}\right)}{\frac{1}{n'} - \frac{1}{n}}\text{; or,}$$

$$x = \frac{m}{\frac{1}{n'} - \frac{1}{n}} - \frac{E}{y} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{B.}$$

where y is the number of hours during which the space is occupied.

When y is infinitely great, or E infinitely little, then

$$x = \frac{m}{\frac{1}{n'} - \frac{1}{n}}, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{C.}$$

This is identically Morin's formula, when E, of his formula A, is infinitely little, and must be the natural one for all cases, the capacity of the space occupied in ordinary circumstances so little affecting the matter that it may be safely neglected.

A favourable specimen of pure air is generally admitted to contain $\frac{4}{10,000}$ of its volume of carbonic acid.................... $\frac{1}{n}$.

When the vitiated air of inhabited places begins to be perceptible by its smell, it is found by authorities in the matter to contain $\frac{8}{10,000}$ of its volume of carbonic acid,.. $\frac{1}{n'}$.

The volume of carbonic acid and watery vapour in the air at

temperature 60° F., expired in an hour by a healthy subject, and which requires to be removed, I assume, for simplicity, to be 1 cubic foot,..m. (The authorities quoted by Morin give 0·0323 cubic metres, which he uses as 0·03, or 1·06 cubic feet.) With these data introduced, $x = \frac{1}{0{\cdot}0008 - 0{\cdot}0004}$, or 2,500 cubic feet, the volume of air which requires to be supplied and extracted per hour per individual, in order that the air of the room may not contain more than $\frac{8}{10{,}000}$ of its volume of carbonic acid. An arithmetical solution of the question, without the aid of symbols, is easily seen from equation (C)—

$$\text{or } \left(\frac{1}{n'} - \frac{1}{n}\right) x = m.$$

Thus, if the air entering an inhabited room contains $\frac{4}{10{,}000}$ of its volume of carbonic acid and watery vapour, and if the air leaving it contains $\frac{8}{10{,}000}$, the difference between these quantities must have been added by the occupants. And if one individual in an hour expires 1 cubic foot of carbonic acid and watery vapour, this amount must be equal to $\frac{4}{10{,}000}$ of his share of the air which passed through the room. Therefore $\frac{10{,}000}{4}$ or 2,500 cubic feet per hour per individual passed through the room.

DISCUSSION ON MR. NAPIER'S PAPER.

In answer to a question, Mr. NAPIER said that he had no experience as to the amount of air which might be passing through a room, when it was so vitiated as to be perceptible by its smell. 1,000 cubic feet per hour was about the greatest amount hitherto assumed to be necessary. He thought that we could not possibly get too much fresh air; but that it became a very expensive matter to heat it to an agreeable temperature. Therefore we had to be content with less, or as much as we could afford to pay for.

Mr. SCOTT said,—If Mr. Napier has some hesitation in criticising the work of so great an authority as Morin, much more may such an one as myself. I have had an opportunity, however, of looking

over Morin's paper at leisure, and am perfectly satisfied that the correction advocated is fully warranted by the conditions of the problem.

As to the arithmetical values that should be given to the various expressions in the formula, opinions will differ. Carbonic acid is only a convenient approximate measure of the impurity of an atmosphere, not being nearly so injurious itself as the organic exhalations by which it is always accompanied. And so long as estimates differ as to the average quantity of air respired by an ordinary individual in an hour, and the extent to which he loads it with carbonic acid in the process; and, still more, as to the proportion of this impurity which may safely be allowed in air which has to be breathed, estimates must necessarily differ as to the quantity of fresh air needed.

Dr. Angus Smith says, "When in very good condition one may bear 4 per cent. of carbonic acid in the air for a quarter of an hour. It is probable, however, that to live all the twenty-four hours of the day in any atmosphere containing more than 1 per cent. would have an injurious effect on the health very rapidly. But leaving out all details, the great broad fact remains, that carbonic acid and other emanations from the body, diminish the blood circulation, and hasten the respiration, and this effect is perceptible when the carbonic acid amounts to ·18 per cent., or 18 parts in 10,000." Dr. Smith is also of opinion that even 6 or 8 parts of carbonic acid in 10,000 parts of air, would be more or less injurious to health.

Assuming then, with Mr. Napier, that the maximum of carbonic acid which should be permitted is 8 parts in 10,000 of air, I have, by an independent calculation, on data principally taken from Roscoe, estimated the quantity of fresh air required at 2,500 cubic feet per hour, for each individual, when the apartment is to be occupied continuously. This is not very far from Mr. Napier's estimate based on Morin's data.

As exhibiting the necessity for better ventilation in the houses of the poor, and at the same time shewing the kind of atmosphere which may be breathed without killing quickly (however surely), the following figures may be of interest. They represent the results of a very extensive series of experiments made some years ago by Mr. Cochrane, a gentleman connected with the Andersonian University, with the view to ascertain the composition of air in sleeping apartments during occupation—principally between midnight and 5 A.M.—in different classes of dwellings in the city. The

experiments were very numerous, and, I am assured, were made with the aid of the best appliances, and conducted with the greatest care. In the best class of west-end houses, the air was virtually quite pure; but in what are known as "ticketed houses," the case was very different. For simplicity's sake I have tabulated and averaged Mr. Cochrane's published figures, and, avoiding fractions, confine the present remarks to the *extra* number of parts of carbonic acid, over and above the normal quantity (between 4 and 5 parts), in 10,000 parts of air.

Dividing the houses into three classes:—(1.) Those having less than the authorised number of inmates; (2.) those having exactly the number; and (3.) those having more than the number (or "over-crowded"), the *extra* parts of carbonic acid (principally from animal sources) to 10,000 parts of air were as follows:—

(1.)	Varying from	26 to 81,	and averaging	45.
(2.)	"	31 to 118,	"	48.
(3.)	"	36 to 85,	"	51.

One of the very worst cases was in class 1, where a room ticketed as sufficient for three persons was occupied by only one— who (as if with a laudable desire to illustrate Mr. Napier's views, and demonstrate the futility of trusting to the size of the room alone), had, by carefully excluding the fresh air, succeeded in obtaining an atmosphere containing no less than 85 parts (81 extra) of carbonic acid in 10,000 of air; or about twenty times the normal quantity.

PROFESSOR THORPE—In fixing upon any standard, such as $\frac{8}{10,000}$ of carbonic acid, regard must be had to the circumstances under which that gas is produced. Air containing $\frac{8}{10,000}$ of carbonic acid would be more vitiated if produced by the respiration of human beings than if produced by the combustion of coal-gas, on account of the readily decomposable organic matter which is expired in the process of breathing. It seems remarkable that no exact comparison has been made between the vitiating power, measured merely by the carbonic acid, of respiration and of the burning of coal-gas. In his paper on the "Economy of Fuel in Domestic Arrangements," Mr. Napier stated that jets using five cubic feet in an hour made the air as impure as eight or nine people would do in the same time. Now, if by impurity is meant the carbonic acid produced by the two processes, it is a matter of simple

arithmetic to calculate the relative degrees of vitiation. I would have instituted the comparison between expired air and Glasgow coal-gas, but the average composition of this gas was unknown to me. Dr. Wallace would doubtless have been kind enough to give me the requisite data, but I had not time to apply to him. I have therefore taken the average composition of Manchester coal-gas as my starting point. The results will thus perhaps be more generally true, as this gas, although much poorer in hydrocarbons than our own gas, would more nearly represent the average composition of coal-gas in general.

The composition by volume of Manchester coal-gas has been stated as follows :—

Hydrogen, ...	45·58
Marsh Gas, ...	34·90
Carbon Monoxide, . . .	6·64
Ethylene, ...	4·08
Tetrylene, ...	2·38
Sulphuretted Hydrogen, . .	0·29
Nitrogen, ...	2·46
Carbonic Acid, ...	3·67
	100·00

I find that 100 litres of this gas would require 0·76 kilos. of air to burn it completely, and produce 0·107 kilos. of water, and 0·124 kilos. of carbon dioxide. Turned into British weights and measures, this would mean that 5 cubic feet of coal-gas would give about $6\frac{1}{4}$ cubic feet of water vapour and $3\frac{1}{10}$ cubic feet of carbon dioxide. Now, an individual expires about half a litre of water in 24 hours—that is to say, if all the moisture in one's breath were condensed to water, its volume would amount to half a litre. This, in round numbers, would be equivalent to 1 cubic foot of watery vapour per hour. Dr. Angus Smith gives the amount of carbon given out in a day by the lungs as 7·55 ounces: this would be equal to 35·4 grams of carbon dioxide, or 18 litres; or, in round numbers, about $\frac{6}{10}$ of a cubic foot per hour, on the supposition that the amount of carbonic acid is distributed equally over the 24 hours. It would thus appear that 5 cubic feet of gas do as much injury, measured by carbonic acid, as five individuals. This may be expressed by saying that two gas-lights do as much harm, so far as carbonic acid is concerned, as five persons. It is worthy of note that the relative amount of carbonic acid and aqueous vapours produced by breathing and by the combustion of gas is very nearly the same.

VII.—*On the Effect of Loch Katrine Water on Galvanized Iron.* By MR. JAMES R. NAPIER, F.R.S.

[Read before the Society, April 1, 1874.]

PART of the cooking machinery recently described in a paper on "The Economy of Fuel in Domestic Arrangements" consisted of a peculiarly-shaped kettle and a water-heating vessel or boiler.

I was aware of the fact, that tinned iron decays very rapidly when water gets access to the iron, at however small a point; and that it is very difficult, if not impossible, to procure iron so thoroughly tinned that no points of iron are exposed. I desired to have a cheap kettle and water-heater, and at the same time save an expensive renewal of either. I was advised to try galvanized iron in preference to tin, on account of the different electric positions in which tin and iron, and zinc and iron stand. In the tinned iron, the iron dissolves, and the tin remains unaffected when both are exposed in contact in water: we then have rusty water-making inky tea and coffee. In the zinc-coated iron the zinc dissolves, and the iron is preserved when both are exposed in contact in water. It did not occur to me, however, to inquire what would become of the dissolved zinc, or if it was injurious to health. I assumed that iron was as thoroughly coated with zinc by the so-called galvanizing process as it was with tin by the tinning process; and from the fact that the highest chemical authorities state that pure zinc is insoluble in pure water, inferred that there would be no dissolved zinc to trouble one for years.

I inferred also, from seeing so many iron vessels coated with zinc, and used for ships' water tanks, and many domestic purposes, without any notice or warning of their unsuitableness or unhealthiness, that there was little or nothing to object to in their use. The fact, however, is otherwise. The zinc with which iron goods are coated in the galvanizing process, dissolves very rapidly from such goods in Loch Katrine water. The water in my kettle becomes quite milky while remaining ten or twelve hours in it, little floculent matter appearing all through it. Loch Katrine water left for a

night in a new, that is, in a previously unused galvanized iron bucket, has the same floculent matter in it. I infer, therefore, that galvanized iron vessels are wholly unsuitable for water tanks or cooking utensils, using such water as Loch Katrine supplies, unless some unreported or unexplained manipulation is previously resorted to, which prevents the action referred to above.

Discussion on Mr. Napier's Paper.

Mr. Mayer—Perhaps the milkiness is due to a carbonating process going on in the water.

Professor Thorpe—In answer to Mr. Mayer, I may say that this milkiness is due to carbonate of zinc. However long the water is kept in contact with the zinc the action will go on, provided air has access to the water. Lead gets a thin coating of oxide and carbonate which protects it, but this apparently is not the case with the zinc.

Mr. Napier—Is it poison?

Professor Thorpe—Yes; it is poison.

Mr. Whitelaw—My attention was called to this some time ago, from seeing action go on in a galvanized iron pail, when alkali was put in it. In a porcelain vessel the action of caustic alkali on zinc is not powerful, but immediately on putting in a handful of iron nails, powerful action ensues, and hydrogen is given off, shewing that water is decomposed by the formation of oxide of zinc, which combines with the alkali, forming a zincate.

When caustic soda is fused in an iron ladle, and a piece of zinc introduced, very energetic action takes place.

Mr. Napier afterwards shewed some pieces of a boiler given him by Mr. Norman, which had been originally coated by the galvanizing process, but which in the course of eighteen months had entirely lost the coating of zinc, and the iron had also been corroded.

VIII.—*On the Methods in use for determining the Value of Animal and Vegetable Oils.* By MR. J. J. COLEMAN, F.C.S.

[Read before the Chemical Section of the Society, Jan. 12, 1874.]

IT is not easy to get at an accurate statement of the number of the fixed oils having a vegetable or animal origin, and which, having been examined or brought into use, have been found to differ from each other more or less in physical constitution or practical utility.

Watts enumerates, in his *Chemical Dictionary*, forty-nine vegetable oils, eleven fish oils, and five animal oils, making a total of sixty-five. This list is defective, as it does not include some Indian products shewn in the Exhibition of 1851, nor do we find the oleins obtained from tallow or cocoa-nut oil alluded to.

Each of these fixed oils have some distinguishing characteristics. Having a generally family resemblance—no two are exactly alike. Upon the possession or non-possession of certain valuable qualities, esteemed by consumers of oil, depends the practical applications of the oils, checked, however, from time to time by the relative scarcity or abundance of the oil; these two considerations establishing the market value.

Accordingly, we find upon examining brokers' circulars or Board of Trade returns for the last five or ten years back, one particular class of oil having an average yearly value of, in round numbers, £95 per ton, represented by sperm oil; a second class, £60 per ton, represented by animal oleins; a third class, £50 per ton, represented by the various qualities of olive oil; a fourth class, £40 per ton, represented by rape oils; a fifth class, £35 per ton, represented by the drying oils; and a sixth class, about the same in price, represented by the stinking fish oils.

So great relative variations in price amongst the different classes enumerated shew that, for practical purposes, they differ very much in utility; and we can scarcely suppose that the dealers in and consumers of oil, who have something considerably more than 100,000 tons, or 25,000,000 of gallons, passing through their hands yearly, of the aggregate value of at least five or six millions of pounds

sterling, can preserve such class distinctions amongst oils, year after year, without some solid basis, which deserves the careful attention of the chemist.

And these differences in the properties of the fixed oils is by no means always dependent upon the mucilaginous, albuminous, or odoriferous impurities they contain. There are actual differences in the properties and perhaps constitution of the olein, palmitin, or stearin of which they are constituted, more especially, perhaps, in regard to their susceptibility of ready oxidation by atmospheric oxygen.

The precise nature, however, of the variations in the proximate principles of oils is very little understood; indeed, if we had accurate knowledge on the matter, we might be able perhaps soon to boast of being able to make a commercial analysis of oil of some value. As the matter now stands, in reference to detecting adulteration of animal or vegetable oils, all we can boast of are a few empirical tests, some of them of doubtful character, by which the absence of certain oils in mixtures can be sometimes inferred, and in a few cases the proportion in which they exist can be roughly guessed at.

When we consider the labour and perseverance required in order to get thoroughly acquainted with the individual characteristics of the chemical elements, it is obvious that, to get similarly acquainted with the characteristics of the fatty oils, which are of greater number than those of the elements, is no light task.

I therefore propose to point out, in a subsequent part of this paper, how, in the examination of commercial oils, we can much simplify our work by eliminating all such oils, as, by reference to brokers' or merchants' circulars can be proved, have over a series of years been always dearer than the supposed oil under examination. It may be taken as a commercial maxim that no man adulterates for the benefit of the public when it entails loss to his own pocket.

Before going further into this part of the subject, it will be advisable to pass in review the chemical and physical tests which have been proposed for detecting adulteration in oils.

Colour Tests.

The most elaborate work in this direction was undertaken by the late Professor Calvert, who studied the action of acids and alkalies of different states of dilution upon oils, in special reference to the colour and appearance of the mass, formed by combining one part

of the reagent with five parts of oil (at normal temperatures in the case of the acid, at boiling temperatures in case of the alkali).

The reagents Calvert used were—

1° Caustic Soda, of	. . . .	1·340 Sp. Gr.
2° Sulphuric Acid,	. . . .	1·475 ,,
3° ditto,	. . . .	1·530 ,,
4° ditto,	. . . .	1·635 ,,
5° Nitric Acid,	. . . .	1·180 ,,
6° ditto,	. . . .	1·220 ,,
7° ditto,	. . . .	1·330 ,,

8° The product of No. 7 treated with twice its bulk of Solution Caustic Soda and boiled.
9. Mixture of concentrated Sulphuric and Nitric Acid.
10. Aqua Regia.
11. The product of No. 10 treated with twice its bulk of Caustic Soda Solution and boiled.
12. Syrupy Phosphoric Acid.

Calvert furnishes us with tables of results comprising 180 reactions, the observer to notice various shades of colour produced. The colours in a few cases, as in the reactions with fish oils, are decided and marked, but a large number of them appear to be of a very nondescript character, such as brownish, greenish, yellowish, dirty white, dirty green, slight yellow, &c.

The observer has also to observe the fluidity or non-fluidity of the mass, resulting from the action of caustic soda upon the oil.

Now, on examining Calvert's tables, it will be observed that he only experimented with fifteen oils, these very important commercial oils—tallow, olein, and cotton-seed oil—being entirely omitted, besides about fifty others of minor importance. It is sufficiently formidable having to study Calvert's 180 reactions, especially when we take into account the great prevalence of partial colour blindness; but the task becomes very formidable if it becomes necessary to acquaint ourselves with the colours which would be produced in similar circumstances by the half-hundred or so of other oils not included, and which may probably give reactions which might be confused with those of the oils already examined.

I feel also inclined to think that many of the colours produced may be owing to the presence of more or less mucilaginous matter, or small portions of the inspissated juices of the plant or animal which really have no great bearing upon the genuineness or adaptability of the oil for the purpose for which it may be required. Calvert himself does not state whether he used refined oils or not.

Thus, rape oil is used by the public both refined and unrefined, the latter being called brown rape or sweet oil; and the olive oils are generally used unrefined, though olive oils refined as white as water, are known in the market. The particular extent to which an oil is refined will probably give great variety of shades. Thus, I have noticed a refined rape oil from Germany give, with the 1·635 sulphuric acid, quite a different colour from a sample from Belgium; still there was enough evidence of other kinds to convince me both oils were genuine; and precisely the same remarks apply to two samples of cotton-seed oil, one refined in the United States, the other refined in England.

Calvert states himself that the colour test is not applicable for detecting some oils. In dealing with a supposed mixture of lard oil and rape oil, he says, the colour reactions not being decisive, one conclusive test will distinguish them—viz., that after treatment with aqua regia and subsequent boiling with caustic soda, lard oil will give a fluid mass and rape oil a fibrous mass. Now, I repeated this experiment not only with lard olein, but with tallow olein, and found that the caustic soda gave even a more fibrous mass with tallow olein than with rape oil, although his remarks about lard olein are quite correct; but this experiment shews that his tables, to say the least, are very defective, and in this particular case worse than useless, without some other tests, inasmuch as an animal olein of equal value to lard olein gives the characteristic reaction of rape oil which Calvert relies upon.

However, some of Calvert's more marked reactions are sometimes useful and valuable as adjuncts, and the special cases to which they apply will be referred to shortly.

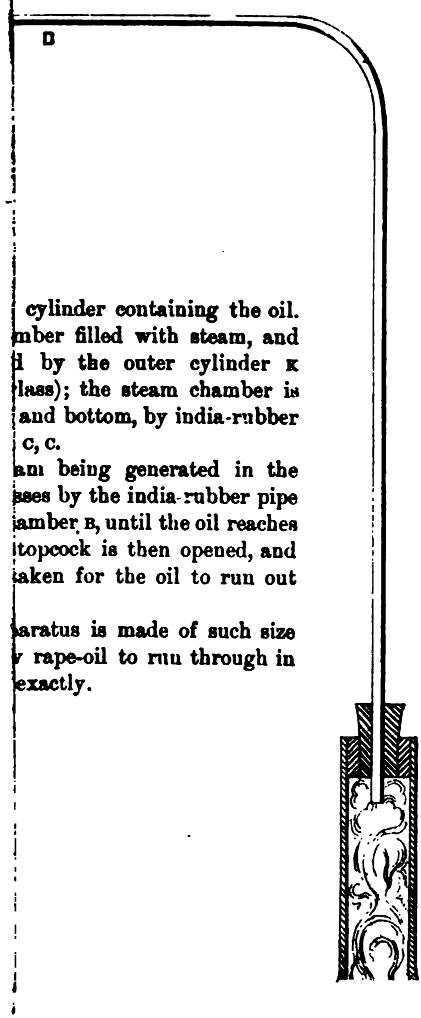
M. Heidenrich, M. Penot, and M. Marchand, have also proposed colour tests from the reaction of concentrated sulphuric acid upon oils, employing only a few drops of the oil placed upon a porcelain plate; but these methods are open to the same doubt and uncertainty as those of Calvert, particularly to the extent or nature of the colouration depending upon the accidental impurities of the oil.

Thermometric Tests.

A method of distinguishing fatty oils by the difference in the amount of heat produced by mixing one part of sulphuric acid with three parts of the oil to be tested, was suggested by Maumené and elaborated by Fehling. The idea is pretty, easy of execution, and interesting in results.

E TERM VISCOSITY

OLEMAN.



cylinder containing the oil.
mber filled with steam, and
l by the outer cylinder K
lass); the steam chamber is
and bottom, by india-rubber
C, C.
am being generated in the
sses by the india-rubber pipe
amber B, until the oil reaches
topcock is then opened, and
aken for the oil to run out

aratus is made of such size
y rape-oil to run through in
exactly.

air bath, kept at a temperature of from 180° to 200° Fahr. After

a certain length of time characteristic of each oil, the mass enters into active combustion. Mr. Galletly's figures are as follows:—

	h.	m.
Boiled linseed,	1	15
Seal oil,	1	20
Raw linseed,	4	0
Lard oil,	4	0
Gallipoli olive,	5	0
Refined rape,	9	0 (about)

Equal parts mineral oil and seal oil refused to ignite.

I repeated Mr. Galletly's experiments with the special view of studying the action of mineral oil in preventing or retarding the combustion; and the results I attained were as follows, special attention being also directed to the effect of substituting wool or jute waste for the cotton. Mr. Galletly's experiments were made between 130° and 170° Fahr., and mine between 180° and 200° Fahr:—

	h.	m.
Seal oil on wool,	3	0
Whale oil on wool,	3	15
Whale oil on cotton,	3	0
Whale oil on jute,	9	0
Olive oil on cotton,	4	0
Oleic acid on wool,	13	0
Olive oil with 20 per cent. mineral,	8	0

The following mixtures refused to ignite after twenty-six hours' exposure:—

Equal parts olive and mineral oil on cotton.
,, ,, whale and mineral oil on jute.
,, ,, seal and mineral oil on wool.
,, ,, oleic acid and mineral oil on wool.
Oleic acid with 20 per cent. mineral oil on wool.

Thus it was rendered evident that the addition of mineral oil to animal and vegetable oils, has so powerful an effect in retarding oxidation (which is presumably the cause of spontaneous ignition), that the presence of even 20 per. cent. delays combustion some hours, whilst 50 per cent. prevents it altogether.

Drying Properties.

The relative drying properties of oils is a most important point. All oils above the value of rape oils are considered commercially as non-drying oils; but there is much reason to believe that the transition from drying to non-drying oils is not so clearly marked

as is sometimes supposed. The order in which the drying properties gradually develop themselves is somewhat as follows:—Animal oleins, olives, Lisbon seed, rapes, ground nut, sunflower seed, cotton seed, poppy seed, and other fancy seed oils, and finally, linseed oils. This excludes the fish oils, which constitute a class by themselves, and which are generally supposed to be non-drying.

Under the name of fancy seed oils, I include a number of oils we know little about, and which have generally more drying properties than rape oil, and less than linseed oil. Cotton-seed oil is the chief representative of this class of oils; and they seldom reach the consumer under their proper names; but are used, on the one hand, to adulterate the so-called non-drying oils—olive and rape, thus making them clog or gum, which interferes with their uses for lubricating machinery, burning in lamps, &c.; or, on the other hand, for adulterating linseed oil, which they injure also in another direction, by spoiling its drying properties for paints and varnishes.

How far the drying of oils is to be measured by their relative powers of absorbing oxygen is an interesting chemical question; and is worthy of a systematic course of experiments, which perhaps I or Mr. Galletly, who entertains the same views, may be able to accomplish at some future time—either by actually weighing the oxygen absorbed, under similar circumstances, by pure specimens exposed to, say, a temperature of 200° Fahr. in thin layers, or by the use of some oxidising agent.

As to the practical methods of judging of the more or less drying properties of oils, we have—

1st. The nitrate of mercury test, which indicates, by the consistency of the mass subjected to the reaction, the greater or less drying properties of the oil under examination—rosin oil, mineral oil, and the drying oils proper, refusing to solidify, whilst the so-called non-drying oils solidify by the formation of elaidin.

2nd. The method of comparing a sample under examination in a shallow capsule to 200° Fahr. with a similar quantity of similar oil known to be pure.

3rd. The imbuing thick white blotting paper with the oil under examination, and comparing it with a similar experiment with known pure oil at, say, a temperature of 150° to 200° Fahr., for some hours, or at ordinary temperatures for some days.

Specific Gravities.

We now come to the question of specific gravity. The taking of the specific gravity of an oil is one of the very first of the ideas

which will occur to a chemist as a means of identification; and accordingly we find accurate experiments have been made in this direction with most of the animal or vegetable oils, and by a great number of persons, so that most chemical or technological books contain clear and valuable information on the point.

Accurate determination of the specific gravity of oils is of consequence; and I have often had occasion to remark the very slip-shod manner in which oil merchants deal with the matter.

They generally employ an instrument called an oleometer, marked with some arbitrary degrees, certain figures standing for particular oils marked on the stem. The defect of this instrument is its long range. From the limited length of the stem small differences in specific gravity escape notice.

The oleometers used for testing oils should be marked with the ordinary specific gravity degrees, water being 1,000, and the space allowed on the stem for each degree should not be less than 1-16th of an inch.

This may necessitate the employment of two or three glasses for specific gravities, ranging between ·880 and the heaviest of oils. Too long a stem is inconvenient, especially when we have only small samples of oil to be tested. Our oil merchants are also apt to be careless about the temperature at which the specific gravity requires to be taken, viz., 60° Fahr. As a rough rule, for temperatures near to 60° Fahr., it is sufficiently accurate to allow 1° decrease of specific gravity for every 2½ per cent. excess of temperature above 60°. The fatty oils do not, however, expand quite equally, so that it has been proposed to compare specific gravities at some high point, say, 212° Fahr., as a means of detecting adulterations.

This suggestion may be valuable as an adjunct to other methods, but does not afford much hope of being reliable of itself.

The rule of adding 1° in specific gravity for every 2½° temperature above 60° Fahr., and *vice versa*, subtracting 1° from the indicated specific gravity for every 2½° below 60° Fahr., is sufficiently accurate for ordinary purposes.

Mineral and Rosin Oils.

We have now discussed the methods which have been suggested as means of detecting adulteration in animal and vegetable oils; but before proceeding to the consideration of their applicability to individual cases of supposed adulteration, we must first, as an indispensable preliminary to any investigation of the sort, prove the absence of mineral and rosin oils from the samples under examina-

tion. The presence of mineral oil in a mixed oil submitted to the chemist for examination must not be considered as an adulteration, if the oil is sold as a prepared spindle, machinery, or engine oil. In such a case the mineral oil is probably a valuable constituent of the oil, and is added for the purpose of reducing the tendency to gumming common to many fatty oils, or else with the direct purpose of reducing the viscosity of the oil, so as to enable it to work freely upon certain classes of machinery. This prepared or mixed oil trade is *legitimate*. When, however, oil is *sold* as a pure animal or vegetable oil, and contains mineral oil, then it becomes a case of adulteration.

Whether the presence of mineral oil be legitimate or not in the sample under examination—if it does exist, then there are great difficulties; for, unfortunately, when mineral oil is once mixed with a fatty oil, we have no easy method of separating it without actual destruction of the fatty oil, and its presence prevents the identification of the particular fatty oil. Saponification naturally suggests itself, but practically the process is not efficient; for mineral oil unites with the soap produced, whether mechanically or chemically does not seem clear; at any rate, mineral oil forms an emulsion with soap solutions—which frequently shew no signs of separation after standing for weeks or months.

Perhaps the formation of a lime or other earthy soap, and its reduction to powder, and the subsequent extraction of the hydrocarbons by a volatile solvent, might afford some result both with mineral and rosin oil. But the most satisfactory method would probably be an *ultimate* chemical analysis, as the presence of mineral or rosin oil hydrocarbons must wonderfully alter the relative proportions of carbon, hydrogen, and oxygen in a fatty oil.

In practice, however, mineral oil can be easily detected by two characteristics:—*Firstly*, The *fluorescent* properties it imparts to all animal or vegetable oils; and, *Secondly*, the strongly marked aromatic burning flavour it communicates to mixtures containing it. The first-mentioned property is brought out by smearing a metallic surface, such as tin-plate or steel, with the oil, and then viewing it at different angles in the open air or sunlight. So characteristic is this, that most mechanics who use oil, can detect mineral oil at once, even when present in very small quantities.

If, however, a chemist gets a dark-coloured oil to examine—for instance, a dark Gallipoli or brown rape—it may be necessary to refine the sample by successive treatments with concentrated sul-

phuric acid and weak soda solution, or lime water (in the way oils are usually refined). Mineral oil can then be *detected* in the sample (which can be cleared by filtering through cotton wool) by a pale, azure blue ring, about the sixteenth of an inch deep, at the junction of the surface of the oil with the sides of a glass jar—the jar being held on a level with the eye, and the line of vision being at right angles to the beam of light. On looking from below upwards through the oil, the under portion of the surface of the oil exhibits a similar beautiful pale azure blue *sheen*.

It is easy to detect as small a quantity as 2½ per cent. in fatty oils by this method, combined with the *tasting* of the oil. Mineral oil may be sometimes detected by the smell; but this must not be depended upon, as recent improvements in the manufacture of oils have rendered it nearly odourless. It should, however, be remarked that the presence of traces of nitrobenzol or analogous substances masks the fluorescence natural to mineral oils.

The absence of rosin oil must also be proved. The action of nitric acid upon the oil at ordinary temperatures is a test sometimes used—the colour developed being said to be much greater when rosin oil is present than when absent. This test, however, I have not found very satisfactory. The presence of rosin oil, even only to the extent of 10 per cent., in an oil which would produce solid elaidin by the nitrate of mercury test, has the effect of retarding or preventing the solidification which would otherwise occur with pure oil subjected to the test.

The importance of being sure of the absence of mineral or rosin oil before proceeding to test specific gravities, cannot be too much insisted upon, because mineral oil, ranging in specific gravity between ·800 and ·900, and rosin oil being nearly 1·000, adjustments in specific gravity resembling the gravity of the natural oils can be easily effected, so as to completely upset all our subsequent classifications dependent upon specific gravity.

Classification for Practical Examinations.

We now proceed to an attempt to classify oils on the principles indicated in the earlier part of this paper.

Class I. contains only one member—sperm oil—which, for a long series of years, has held the position of being the dearest oil in the market. Its commercial value is dependent upon the fact that only 3,000 tons are imported annually into this country; and, secondly, upon the fact that, for a particular class of work—viz., the greasing

of spindles of cotton, woollen, or worsted mills, it has been found to answer better than any other vegetable or animal oil.

Now, the two reasons which appear to establish the efficiency of sperm oil for this particular purpose are, the small viscosity of the oil, combined with its freedom from all tendency to gum or dry on the machinery.

A cotton spindle is sometimes scarcely larger than a big penholder, and there are sometimes, say, in one mill, 40,000 or 50,000 of these, revolving at the rate of from 2,000 to 10,000 revolutions per minute. It is obvious that the great viscosity of the other fatty oils, if used for greasing them, would offer a resistance to their motion of no mean character. Accordingly we find oils which would suit an engine or big shafting, when applied to the bearings of a spindle, necessitate the employment of much more power, and, as a necessary consequence, the consumption of more coals than is required when sperm oil is used.

Now, the quantity of sperm oil coming into this country is far too small to supply even a fraction of the spinning mills of the United Kingdom: even twenty years ago the scarcity was felt, and the price reached 20s. per gallon. The great substitute for sperm oil in our days, for this special purpose, is mineral oil, which, by suitable combination with other oils, produces a product which is of that small viscosity or limpidity characteristic of true sperm oil—so that now we find most spinning mills using such preparations.

From its scarcity and high price, sperm oil is liable to adulteration. The oils known to be lighter than sperm oil in specific gravity are certain mineral oils, and an oil which comes in small quantities into this country as African fish oil; whilst, on the other hand, the oils known to be heavier than sperm oil are all the other fifty or sixty oils known in commerce, most of them fully 30° or 40° heavier in specific gravity.

The specific gravity of sperm oil is stated in chemical books to be ·875; but the assertion is made by dealers that the young fish give a lighter oil than the old fish. Three principal refiners of sperm oil—viz., Langton & Bicknell and Millers, of London, and Walls & Co., of this city—are supposed to be reliable; and I have found samples of guaranteed genuine oil from them stand ·882, or thereabouts.

Whether this must be considered correct is an open question; at any rate, it is clear that sperm oil should never be heavier in specific gravity.

The specific gravity being correct, does not necessarily imply the genuineness of the oil, because the specific gravity could be adjusted

by mixing African fish oil, or mineral oil, with some of the heavier oils. In examining sperm oil it is necessary, therefore, to note the following points:—

1st. To examine for mineral oils.

2nd. To examine into the drying properties of the oil, which is best done by exposing to 200° Fahr. in thin layers, or by the use of bibulous paper.

3rd. That the other fish oils darken much more notably than sperm oil, when shaken up with dilute sulphuric acid.

4th. That the most likely adulterant is African fish oil, which produces intense heat when mixed with concentrated sulphuric acid; thus, a mixture of one part of acid and four parts of oil produces a development of heat equal to about 112° Fahr., against a development of heat equivalent to upwards of 250° Fahr. with the African fish oil. (The specific gravity of this African fish oil is ·866, and it is a very bad lubricant.)

5th. That as the use of sperm oil is dependent upon its viscosity, an accurate test thereof in a suspected sample may be useful.

Class II. comes next in value to sperm oil,—viz., the oleins obtained by pressure, hydraulic or otherwise, from animal fats, and known in the market as tallow olein, lard olein, and neatsfoot oil. These oils have their market value established by the fact that, whilst being of good heavy viscosity, they are practically free from tendency to gumming or clagging by the absorption of atmospheric oxygen. In consequence they are adapted for wool greasing, greasing engines and machinery of a heavy character. They are, however, generally too dear for wool greasing, and their use is almost confined to machinery purposes.

Now, with respect to neatsfoot oil, its importance is very much exaggerated in chemical books. It is only produced in very insignificant quantity; and, from its strong smell and its dark colour and high specific gravity, it is of all other oils the most unsatisfactory to examine and report upon; and there is much reason to believe that the name neatsfoot oil is used merely as a cover for mixtures of very inferior oils, flavoured with a small dash of fish oils. Practically, I believe the grease from which neatsfoot oil is produced is generally passed on to the soap matter—very little neatsfoot oil being found in the market. Further, it must be observed, that what is really valuable in neatsfoot oil is the olein expressed from it, which forms but a small percentage of what is known as neatsfoot oil.

It is otherwise, however, with tallow and lard oleins, especially

the latter, which is of very great commercial importance, and both of them are quite equal to neatsfoot oil in practical utility.

In examining these oils, we have, firstly, variations in quality, produced by carelessness in manufacture—viz., the oil being dark-coloured, for both should be nearly white, or too great smell; for they should both be nearly odourless, especially the lard oil, or else they may have an acid reaction, owing to slight rancidity. This applies more particularly to tallow oil. Secondly, we have the variations in quality produced by adulteration, which will be in the direction of the non-drying properties of the oil being interfered with.

The first step in examining either lard or tallow oil is the specific gravity, which in both cases should be ·915. If the oil is heavier, it may contain fish oils, seed oils, or olive oil, or cocoa-nut olein.

Olive oil and fish oils could be detected by the smell, or by Calvert's colour tests; so that the real difficulty lies with the seed oils—one of which, rape oil, is nearly of the colour and exactly of the specific gravity of animal oleins.

It will be found, therefore, that if a sample of animal olein be too heavy in specific gravity, it will probably contain some of the partially drying oils (of which the chief representative is cotton-seed oil), ranging in specific gravity between ·920 or ·930. The Americans, indeed, who send over immense quantities of lard oil, actually *do* adulterate with cotton-seed oil to a large extent; and one can almost calculate the percentage in the oil by the increase of specific gravity; and the same remark applies to adulteration with a great number of other seed oils.

Those seed oils which cannot be detected by variation in the specific gravity are—rape oil, henbane seed oil, horse chestnut oil, plum kernel oil. The three last may probably be disregarded; so that the chief point is the detection of the rape oil, for which three processes may be mentioned.

1st. Heating the oil to 400° Fahr., and allowing it to cool to 90° Fahr. Tallow and lard oil are rendered odourless, whilst the peculiar penetrating smell of rape oil is developed.

2nd. One part by weight of the oil to be tested is mixed with three parts by weight of concentrated sulphuric acid, and the heat developed is compared with that developed by a similar experiment made with pure oil.

3rd. The nitrate of mercury test is said to detect any drying oil present in animal oleins.

Finally, in regard to these animal oils, lard oil is distinguished from tallow olein by the difference in viscosities.*

CLASS III.—The next class of oils in descending value, and which we may call Class III., are the olive oils. They are known in the market under the name of Gallipoli, Sicilian, Spanish Mogadore, &c., according to the port from which they are shipped, and they vary in colour from a fair yellow to a deep olive green, and in smell from the fair smell of salad oil to the powerful odour of the dark-coloured varieties.

Their commercial value is fixed chiefly by the fact that, possessing most of the good qualities of the animal oleins, as far as being non-drying oils, they are, with the exception of the finer qualities, sometimes inferior to the animal oleins in colour, smell, and contamination with mucilaginous and sugary substances, obtained from the juices of the plant.

There is one specific reason why olive oils preserve their value,—that is, the dictum of the Insurance people, who lay down the law that olive oil is the only oil allowed to be used for greasing wool, unless an extra premium be paid. This dictum is absurd, as all oils should be admitted into mills on an equal footing.

The Fire Insurance Companies say olive oil is the safest; but the experiments of Mr. Galletly and myself contradict this. The result of this state of affairs is, that of the 30,000 tons or so of olive oil imported annually, about one-half probably goes into woollen mills for greasing wool, and that cheap seed oils are sent from this country to the Mediterranean, where they are said to get mixed and returned to us as inferior qualities of olive oil,—thus evading the regulations of the Insurance people. The annual circulars of our London brokers reveal the fact that immense quantities of cotton-seed oil are sent annually from this country to the Mediterranean.

The variations in quality of olive oils are, firstly, those depending upon the way in which it is expressed or manufactured (one of the chief being the care with which the olives are picked and the length of time that elapses between their being stored in heaps in a half-fermenting state, and the time they are crushed), which causes affect the colour and appearance of the oil; and secondly, those depending upon actual adulteration.

In regard to the first, the market value is influenced to the

* It may be observed here, that dark-coloured, strong-smelling tallow oils are sometimes on the brokers' lists—especially the London lists; but these oils are used for the special purposes of soapmaking, and bear values resembling those of the fish oils.

extent of many pounds per ton; and the only way to arrive at a judgment is to obtain familiarity with commercial samples. In regard to the second, *actual adulteration*, our careful consideration is required.

Excepting the particular fine qualities of olive oil, the bulk of olive oils are the cheapest of the commercial non-drying oils; so that we have to look for adulteration with drying oils, fish oils, mineral and rosin oils.

I mention mineral oils and rosin oil especially, because, owing to the dark colour and smell of the bulk of olive oils, they could easily be overlooked in a preliminary examination.

It will be necessary, therefore, in such cases, to refine the oil before looking for mineral oil, which can easily be done, as olive oil is in a manufacturing way refined nearly white, though not to any very great extent; or, as I suggested before, an ultimate analysis may be useful.

The specific gravity of olive oil is ·917. Rape oil, a cheaper oil than olive, would make it lighter, and cotton-seed oil, or the drying oils, varying between ·920 or ·930, heavier; but a proper mixture of the two cheap oils—rape and cotton-seed—could be adjusted exactly to the specific gravity of olive oil; so that we have to depend entirely upon our chemical tests, which, however, should correspond with correct specific gravity.

The fish oils, then, being proved absent by Calvert's tests or the smell, we have to look for seed oils; and the three tests in practical use are—

1st. The well known nitrous acid or nitrate of mercury test, which is used and relied upon by the leading merchants, and the full details of which can be found in chemical text-books, especially Richardson and Knapp's *Technology*.

2nd. The characteristics of the soap formed by liquid ammonia.

3rd. Fehling's tests of the rise of temperature produced by mixing with concentrated sulphuric acid.

4th. The solution of carbonate of potash test.

For lubricating machinery, olive oil appears to be going out of use to a great extent. Its sugary or mucilaginous constituents are liable to ferment and make the oil acid, and so inferior to the animal oils, which, however, can be prevented by refining the oil, which is a considerable expense, and not often done.

An oil extensively used for adulterating olive oil in this country is a seed oil called Lisbon seed oil, which is inferior to olive oil in viscosity, but resembles olive oil in appearance. It is an important

question how far these inferior oils—such as Lisbon seed oil, cotton-seed oil, cocoa-nut olein, sunflower seed oil, &c., can be used for wool greasing; and until the Insurance people remove their restrictions, we cannot get accurate knowledge, as the woollen people can only use them surreptitiously or pay higher premiums.

CLASS IV.—We now pass on to Class IV.—rape oils—of which about 20,000 tons are produced annually by our seed crushers, and about the same quantity is annually imported.

The commercial position of these oils is fixed by their being slightly inferior in non-drying properties to olives, but *superior to them in smell and appearance.* Rape oils, in fact, are the border-land between drying oils and non-drying oils; and notwithstanding their slight tendency to gum, are used most extensively for engine and machinery lubrication, as well as for burning in lamps. Two kinds are known in the market—brown rape, or the oil as expressed from the seed, and called sweet oil, and the same after treatment with sulphuric acid, steaming, washing, and filtering, called refined rape oil.

These oils have assumed immense commercial importance, from the quantity in which they can be produced. There are several varieties of the genus Brassica, from which they are crushed; and the oil expressed from these varieties also varies slightly in specific gravity.

The variety cultivated in France and Belgium gives an oil about ·912 specific gravity; whilst that cultivated in North Germany gives a specific gravity of ·915; and the seed crushed in England, and imported from all parts of the Continent and the East Indies, gives about ·914 to ·916 in specific gravity. This difference in specific gravity of rape oils is also accompanied by similar slight variations in viscosity.

It is important to note the limits within which the specific gravity of rape oil varies, because too much importance cannot be taken in testing the oil to ascertain its specific gravity accurately.

The specific gravity of rape oil should never exceed ·916, at 60° Fahr. If it does, we may be sure of the presence of one or some of the following oils—viz., the fish oils, which are easily detected by smell, or by Calvert's tests, or what is much more probable, other seed oils of a more or less drying character, which I have called fancy seed oils: amongst which the chief are—ground-nut oil, sessame oil, sunflower oil, cress-seed oil, hemp-seed oil, poppy oil, cotton-seed oil, Niger-seed oil, and linseed oil, or cocoa-nut olein, having a specific gravity ranging between ·920 and ·935.

Thus, if a rape oil under examination indicates a specific gravity of ·918, it may contain half its bulk of some other of these seed oils, even though the smell and appearance be not much affected. Most of these seed oils, with the exception of ground-nut oil and perhaps cocoa-nut olein, deteriorate the rape oil by adding to its gumming properties; and ground-nut oil and cocoa-nut olein, being of a commercial value equal or sometimes in excess of rape oil, are scarcely likely to be present.

But amongst all these probable adulterants of rape oil, cotton-seed oil is the most likely to be present. Now, cotton-seed oil, when refined, is about the same colour as rape oil, and even superior to it in smell. It is a more drying oil than rape, but not so drying as to be used for the purposes for which linseed oil is used. It is produced in great quantity in this kingdom—viz., to the extent of nearly seventeen thousand tons annually—and yet it is little known to the general public. Much of it, no doubt, goes into soap manufactures, for which it does well; but its commercial value is always below that of Class IV., or the rape oils, and sometimes even of Class V., the drying ones.

Its cheapness, its abundance, good colour, and freedom from smell when refined, make it of all other oils the best adapted for the purposes of adulteration, and, no doubt, in all cases, to the serious injury of other oils; for if present in an oil used for machinery, or for burning purposes, it on the one hand clogs the wick, and on the other clogs the machinery; whilst, if used for adulterating linseed oil, it interferes with its drying properties.

The ease with which cotton-seed oil can be detected in lard or tallow olein and in olive oil has already been indicated.

Its presence in rape oil is easily detected—first, by the specific gravity of the rape oil being increased; second, by the freezing point of the rape oil being materially raised.

Cotton-seed oil contains much stearin; so that a very moderate degree of cold freezes it, whilst rape oil remains liquid at 32° Fahr.

The other tests applicable to rape oil are those for estimating its drying properties, and which have already been described, and which, when properly carried out, give clear information as to the practical value of the oil under examination.

Finally, the value of the oil is also determined by the degree to which it is refined, there being a difference of 40s. per ton between refined and brown rape oil.

CLASS V.—represented by linseed oil, the quantity crushed in

Great Britain being annually nearly 40,000 tons. Its specific gravity is ·937, at 60° Fahr.

From its dark colour, mineral and rosin oils must be carefully looked for; and in their absence fish oils are easily detected by smell or Calvert's tests; and by far the most likely adulterants, cotton, Niger or other seed oils, will be detected by their

1st. Altering the specific gravity.

2nd. Materially *raising* the freezing point.

3rd. Decreasing its drying properties, which can be proved by direct experiment, as before indicated.

CLASS VI.—We now arrive at Class VI., the fish oils. I think we may safely say, these oils have a commercial value inferior to the other oils, simply because they stink abominably. They are not generally considered non-drying oils; so that, if free from smell, they might be applied to most purposes for which other oils are used. At present their use is limited to soapmaking (especially soft soap), greasing leather, greasing jute before spinning (for which several thousand tons are used annually), burning in coal pits, &c., and other purposes where the smell is not of much consequence.

Their price is to some extent regulated by their relative stinking properties, and partly by their viscosity or body: the thickest kinds—viz., Northern whale and cod, being useful for leather, and the thinner kinds, as seal oil, being useful for burning in lamps. The chief of them are—

Northern Whale Oil.
Southern Whale Oil.
Cod Oil.
Seal Oil.
Shark Oil.

The fish oils are not much liable to adulteration, excepting, perhaps, the pale seal oil; and the most probable oil which would be used for sophistication would be cotton-seed oil. They, however, may be mixed with each other—some varieties, as porpoise oil, and herring oil, and East Indian fish oil, being much cheaper than the others.

The most important points, therefore, will be—

1st. Looking for mineral and rosin oils.

2nd. Examining whether the non-drying properties of the oil are interfered with.

3rd. Examining their viscosities in relation to the purposes for which they may be applied.

As regards soapmaking, probably cotton or other seed oils would have very little effect in deteriorating their value.

Having considered the subject of oils in a manufacturing point of view, I have been led to omit consideration of the oils found in druggists' shops—viz., almond oil, cod-liver oil, and cocoa-nut olein—which will, I hope, not interfere with the practical utility of this paper.

The object of the paper being also to consider the oils from the chemist's point of view, rather than the engineer's, I have not alluded to the growing use of mineral oil for the purposes of lubrication on the grounds of economy. In my paper read before the Institute of Engineers (Scotland), 24th November, 1872, full details are given on this subject, more especially in relation to the recent progress in imparting to mineral oil a viscosity adapting it for use on machinery heavier than spindles, &c.—in other words, making it fit for heavy machinery.

Finally, I have to acknowledge the kindness of friends in supplying information, and particularly of Mr. W. H. Hatcher of Messrs. Price's Candle Co., London.

NOTE BY THE AUTHOR.—In the discussion on this Paper, Mr. T. L. Patterson, F.C.S., called attention to the spectroscopic examination of oils as an adjunct in testing, which might be useful, but would require using with care, as the refining of oils might cause the disappearance of absorption bands peculiar to oils in a crude state. Observations on the other optical properties of oils, such as refractive power and fluorescence, by properly contrived apparatus, might be occasionally useful.

IX.—*On the Measurement of the Chemical Action of Sunlight.* By THOMAS E. THORPE, Ph.D., F.R.S.E., Professor of Chemistry in the Andersonian University.

[Read before the Society, April 29, 1874.]

DR. THORPE commenced by referring to the famous experiment of Newton, by which that philosopher demonstrated the composition of white light. After pointing out the chief peculiarities of the solar spectrum, he alluded to the various actions of sunlight, its heating and illuminating effects, and its power of setting up chemical action. The particular vibrations which were mainly instrumental in effecting chemical change were those corresponding to the blue end of the spectrum. This fact the lecturer proved by exposing a mixture of chlorine and hydrogen gases to variously coloured lights, when it was seen that the blue light was the chief agent in effecting the chemical combination of the two gases. The fact that this mixture of chlorine and hydrogen is so excessively sensitive to the action of sunlight, gave rise to the idea that it might be used as a means of measuring the chemical action of the light; and in 1843, Professor Draper, of New York, constructed an instrument for this purpose, based on that principle. The Tithonometer, as the instrument was termed, was scarcely capable of affording exact results, owing to the lack of experimental evidence as to the conditions of its regular action. Still, Draper was enabled by means of it to determine a few of the more apparent phenomena connected with the chemical action of sunlight, and notably the phenomenon of photo-chemical induction. The instrument of Draper, and the basis upon which it was founded, were submitted to a rigid experimental criticism by Professors Bunsen and Roscoe, who constructed a photometer capable of giving concordant and accurate results. By means of this instrument, which differed in everything but the principle from that of Draper, Bunsen and Roscoe were enabled to determine a number of points connected with the distribution and working of the chemically active vibrations in sunlight. They instituted comparisons between the actinic

power of various flames, and shewed that the visual illuminating power of a flame in no way determines the degree of its chemical activity. They also compared the actinic power of sunlight and various terrestrial sources of light, notably that of burning magnesium; and they threw out the idea, which has been so happily realised, that if magnesium could be economically produced, it would afford one of the readiest sources of chemically active light. In speaking of the *rationale* of the action of sunlight in promoting the union of chlorine and hydrogen, the lecturer referred to the remarkable experiments of Budde, who found that chlorine expanded in a marked manner when exposed to the blue portion of the spectrum; whereas it suffered little or no alteration in bulk when exposed to any other portion. Budde concluded from his observations that the molecules of chlorine are actually dissociated into atoms by the action of the more rapid vibrations, and remain thus dissociated so long as the gas is under the influence of the light. The increased chemical activity of the chlorine may be explained on the ground of its existence in this atomic condition. The action of bodies in the so-called nascent state may be explained by means of the same hypothesis. The lecturer described an experiment, which proved that the power of inaugurating the chemical union of chlorine and hydrogen under the action of light resided in the former gas. The power in sunlight to promote chemical change exercises such an immense influence in the economy of nature, that it is highly desirable that we should possess the means of registering its action by continuous observation. It is, of course, only in this way that we can hope to arrive at a knowledge of the laws which regulate its effects and distribution. The lecturer then rapidly traced the various attempts which had been made to supply a chemical photometer which could be used for regular observation—say, in observatories, where it was just as important to trace the variations in the chemical activity of the light, as it was to determine the variations in the pressure, temperature, and humidity of the atmosphere. He more particularly described the photometer of Roscoe, based on the decomposition of chloride of silver under the influence of light, and he described a number of results which had followed its use in various parts of the world. He shewed a series of curves illustrating the march of chemical intensity of sunlight, from day to day, during a whole year, from measurements made at Kew. The lecturer also described the results of a series of observations made by himself in the tropics—namely, at Para, on the Amazons, a town situated near the equator. These measurements were

interesting, as being the first observations of the chemical intensity of light made in the tropics, and they serve to exhibit the enormous actinic power of sunlight in these regions. As shewing the extreme vagueness of our knowledge respecting the distribution of this actinic power, the lecturer mentioned the hypothesis of Draper respecting the modification in character which sunlight is supposed to assume as we approach the equator; and he also gave the experience of some French observers who were sent out to photograph the antiquities of Yucatan, and who were obliged to discard the camera and take to their sketch-books, on account of the supposed want of chemical power in the sunlight. So far from this being the case, it appeared from Dr. Thorpe's measurements that the chemical activity of the light in Para was actually twenty times greater than on the same day in Kew. In detailing his experience, the lecturer paid a passing tribute to the memory of the late Professor Agassiz, who happened to be also at Para, engaged in his researches on the natural history of the Amazons, and through whose instrumentality he was greatly aided in obtaining facilities for carrying on his observations. Dr. Thorpe then mentioned the results of a lengthened series of measurements which he had made at Moita, near Lisbon, with the primary object of determining the relation of the chemical activity of the light to the sun's altitude; and he also shewed the results of observations made by him at Catania, in Sicily, during the progress of the solar eclipse of December 1870. In conclusion, he exhibited and described the new automatic photometer of Roscoe, whereby the personal labour of observation is reduced to a minimum. The instrument is more particularly well adapted to observatory use; and he expressed the conviction that, by the distribution of instruments on this pattern, our knowledge of the laws regulating the important action of sunlight in promoting chemical change would be speedily augmented.

X.—*On Deep-Sea Sounding by Piano-forte Wire.* By PROFESSOR SIR WILLIAM THOMSON, LL.D., F.R.S.

[Read before the Society, March 18, 1874.]

SIR WILLIAM THOMSON said—I have now to bring before the Society a new process for deep-sea sounding, which has been practised for more than a year with much success. At a Meeting (March 18, 1873) of the Institution of Engineers in Scotland last session, an apparatus of this kind was shewn, and the whole process of using the wire for deep-sea sounding was elaborately explained, so that it is not now necessary for me to enter on details of this subject. I will briefly remark that the great advantage of steel wire over hemp rope, is the comparatively small resistance which the wire experiences from the water. The great amount of resistance which rope meets from the water is well known to sailors. The resistance of even so short a length as 50 fathoms of ordinary deep-sea sounding line going through the water, is very considerable. Common observation in the use of the Massey log, shews that the resistance of a few fathoms of the rope is greater than the resistance of the log itself. The deep-sea lead goes down with great rapidity for 10, 20, or 30 fathoms, but after that depth the resistance of the rope begins to tell seriously, and at 50 or 150 fathoms the resistance to the rope moving through the water is very great. In sounding at these depths the great force required to haul in the rope, at any considerable speed, is well known. The greater part of that force is due to the resistance that the water opposes to the rope hauled through it, and a very small portion is due to the lead. The small area of the wire surface and its smoothness, as compared with the ordinary hemp sounding line, give it a great advantage in these respects. Then, as regards strength, this wire, which is Messrs. Webster and Horsfall's piano-forte wire, No. 22 gauge, bears 230 pounds, and weighs 14½ pounds per 1000 fathoms. The wire I shewed to the Institution of Engineers last year, was not the ordinary quality of piano-forte wire; it was a wire made specially for sounding by

Messrs. Richard Johnson & Nephew, of Manchester. They succe
in making a wire three miles in length, from crucible steel, w
has many good qualities, particularly that of strength; bu
temper was not equal to that of the best piano-forte wire, w
however, can only be produced in much shorter lengths. The
of splice which I had then designed (but only imperfectly te
has since proved so successful that I do not now care so much
length; Messrs. Webster and Horsfall give me lengths of about
fathoms.

In upwards of one hundred soundings on the East and No
coasts of Brazil, in the Pacific, and in the Bay of Biscay, in dep
of from 500 to 2,700 fathoms, partly with Johnson's special wi
and partly with Webster and Horsfall's, there has in no one insta
been a failure of the splice. The splice is made very easily, and
a few minutes.

There is a considerable difference in the mechanism now shewn
the Philosophical Society from that I shewed to the Institution
Engineers last session, but a far more important difference is in t
wire. Wire of an inferior quality is brittle at places, and brea
when it kinks. I believe not a single case of this has happened wit
the Webster and Horsfall piano-forte wire now used.

[Sir William Thomson, at this stage, referring to his new soundin
machine, shewn to the meeting, proceeded to explain the nature
its various parts, and its action as a whole. The machine which h
shewed is represented in the present report by the two accompan
ing Plates, one of which shews it by elevations, sections, &c.; an
the other of which is a perspective drawing made from a photograp
of the apparatus itself. By study of these drawings with the aid
the brief explanatory notes written upon them, together with th
explanations here following, as noted from the lecture, the read
may arrive at a good conception of the nature of the apparatus, an
of the sounding processes for which it is adapted. He continued
as follows:—]

The wire is coiled on a large wheel, which is made as light a
possible, so that, when the weight reaches the bottom, the inerti
of the wheel may not shoot the wire out so far as to let it coil o
the bottom. The avoidance of such coiling of the wire on th
bottom is the chief condition requisite to provide against the poss
bility of kinks; and for this reason a short piece of hemp lin
about five fathoms in length, is interposed between the wi
and the sounding-weight; so that, although a little of the hem
line may coil on the bottom, the wire line may be quite pr

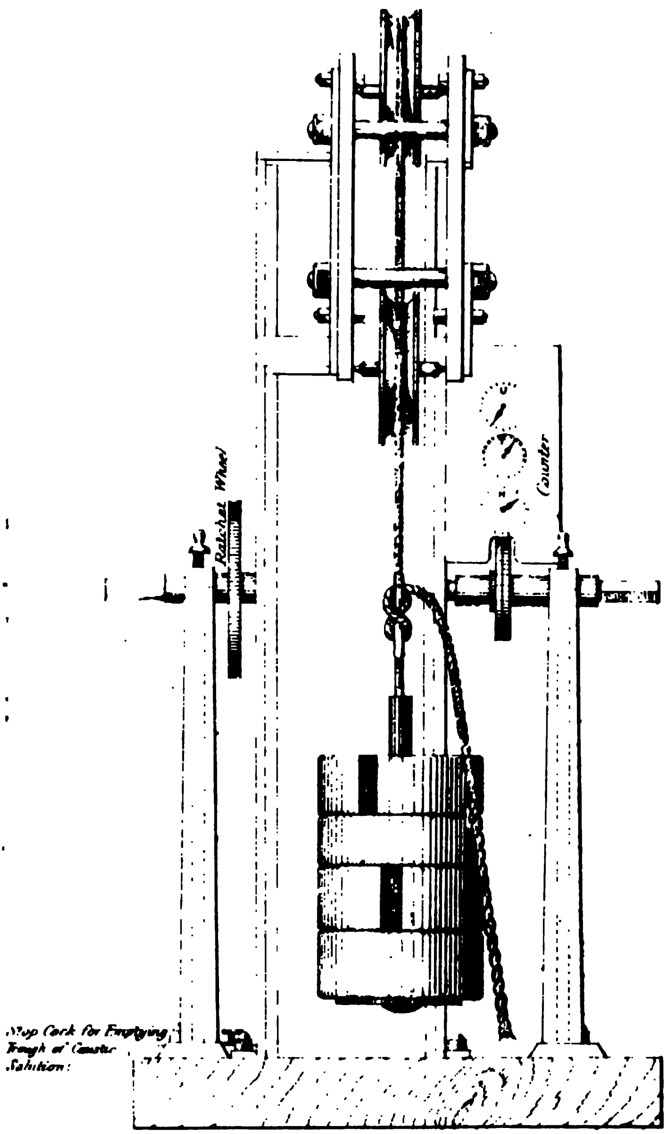
ings of the Philosophical Society of Glasgow, 1874.

ERSPECTIVE VIEW

OF

VILLIAM THOMSON'S

NDING APPARATUS.



BACK ELEVATION OF FRAMING,
CASING, WEIGHT &c FOR SOUNDING WHEEL.

vented from reaching the bottom. There is a clamp, or a ring, attached directly at the bottom of the wire, so as to form the coupling or junction between the wire and the hemp line. The clamp is about 4 or 5 pounds in weight, and either it, or the ring, which may be considerably lighter, and may be used instead of the clamp, suffices to keep the wire tight when the lead is on the bottom, and the hemp line is slackened. The art of deep-sea sounding is to put such a resistance on the wheel as shall secure that the moment the weight reaches the bottom the wheel will stop. By "the moment" I mean within two or three seconds of time. Lightness of the wheel is necessary for this. Whatever length of wire is estimated as necessary to reach the bottom is coiled on the wheel. For a series of deep-sea soundings in depths exceeding 1000 fathoms, it is convenient to keep a length of 3000 fathoms coiled on the wheel. When we do not get bottom with 3000 fathoms, the process of splicing on a new length of wire ready coiled on a second wheel, is done in a very short time—two minutes at most. The friction brake which you see, is simpler in construction than that shewn to the Engineers last session. This is simply a roturn to the form of brake which I used in June, 1872, when I first made a deep-sea sounding with piano-forte wire in the Bay of Biscay, in 2,700 fathoms. The process of sounding is this:—Such a weight is applied to the brake as shall apply to the wire leaving the wheel a resistance exceeding by 10 pounds the weight of the wire out. Thus, commencing with a resistance of 10 pounds, when 100 fathoms are out add 1¼ pounds to the brake-resistance. For every 1000 fathoms of wire out, add 12 pounds to the brake-resistance, because the weight of 1000 fathoms of the wire in water is about 12 pounds. The only failures in deep-sea soundings with piano-forte wire hitherto made have been owing to neglect of this essential condition. The circumference of the wheel is a fathom (with a slight correction for the increased diameter from the quantity of wire on). Hence for every 250 turns of the wheel, add three pounds weight to the brake-resistance. The action down to 2,700 fathoms is perfect. I cannot speak beyond that from personal observation, but nevertheless I can confidently say, that soundings in the greatest depths of the sea which have been hitherto sounded, can be made with this apparatus with perfect ease. Getting back the weight is the most difficult part of the process. In ordinary deep-sea soundings there is a trigger apparatus, by which the weight (300 pounds or 400 pounds of iron) may be detached, and then the rope, with only a tube bringing up a specimen of the bottom, is hauled up. In sounding with the

wire apparatus up to 2,700 fathoms, I use a 30 pounds lead sinker, and I have not found it necessary to use the detaching apparatus, but in depths exceeding 4,000 fathoms, I might be induced to use it. The process of recovering the wire and sinker involves a little difficulty, from the fact that coiling so great a length of wire on the drum under so great a tension, applies a prodigious force to the wheel. Suppose there is a pull of 50 pounds on the wire as it is coiled round the wheel, then we have the halves of the wheel on two sides of any diameter, pressed together with a force of 100 pounds by one coil, or one fathom, of the wire. One thousand times that gives 100,000 pounds pressing the wheel together for about 1000 fathoms, so that if the wheel did not yield a little, we should have (after hauling in lead and wire from a depth of 3,000 fathoms) a pressure of more than 100 tons pressing it together. In point of fact, the wheel yields to some degree. Practically I found that in hauling in the line from 2,700 fathoms the wheel was squeezed out of shape, and came to be something like the shape of the old-fashioned, three-cornered cocked hat. This part of the process has undergone very considerable alterations since 1872. The United States navy have taken up with great ardour the system of deep-sea soundings by piano-forte wire, and have been most successful in practising it. They have worked it out in a way somewhat different from that which I have followed. They get over the difficulty of hauling in by strengthening the wheel, and detaching the weight. I prefer not to lose the lead. If the sounding is less than 1,000 fathoms, the wheel will not suffer. I sounded off Funchal, Madeira, last summer, in 1,200 fathoms, and coiled the wire in safety direct on the wheel. Although the wheel shewed signs of distress, it was not seriously injured. But if we had to haul up from 2,000 fathoms, it would probably be seriously damaged. Therefore, if the depth exceeds 1,000 fathoms we must either strengthen the wheel or detach the lead, or both: or we must relieve the wheel of a great part of the strain. I prefer the latter remedy. The weight of the wire is 14½ pounds per nautical mile in air, and in water about 12 pounds per nautical mile. In a depth of three miles, therefore, we have 36 pounds of wire, 30 pounds of lead, and about 4 pounds of ring or clamp:—in all, 70 pounds. In preparation for hauling in, a spun yarn stopper, attached to the lower framing of the sounding machine projecting over the taffrail, or to the taffrail itself, is applied to the wire hanging down below, to hold the wire up and relieve the wheel from the necessity of performing that duty: or otherwise, two men, with thick leather gloves, can

easily hold the wire up.* A little of the wire is then paid out from the wheel, and the wheel with its framing is run inboard about five feet on slides which carry its framing [see the accompanying drawings†], and the slack wire is carried once or twice round a grooved drum below, which overhangs the bearings of its own axle, so as to allow the loop or the two loops of the wire to be got on. Two handles attached to the shaft of this drum, worked by one man on each or two men on each, take from two-thirds to nine-tenths of the strain off the wire before it reaches its own wheel, on which it is coiled by one man or two men working on handles attached to its shaft.

If the ship is hove to when the wire is being hauled in, the wire will generally stream to one side (if out by the stern, which is the position I now prefer). By having the bearing of the aftermost wheel, an oblique fork turning round a horizontal axis (like the *castor* of a piece of furniture laid on its side), the wire is hauled in with ease though streaming to either side, at any angle. [See the drawings.‡] This castor wheel is a very important addition to the hauling-in gear. (In paying out, the wire runs direct from its own wheel into the sea.)

But it is not necessary to keep the ship hove to during the whole time of hauling in the wire. When the depth exceeds 3,000 fathoms, it will, no doubt, be generally found convenient to keep the ship hove to until a few hundred fathoms of the wire have been brought on board. When the length out does not exceed 2,500 fathoms, the ship may be driven ahead slowly, with gradually increasing speed. When the length of wire out does not exceed 1,500 fathoms, the ship may be safely driven ahead at five or six knots. The last 500 fathoms may be got on board with ease and safety, though the ship is going ahead at ten or twelve knots. Thus, by the use of wire, a great

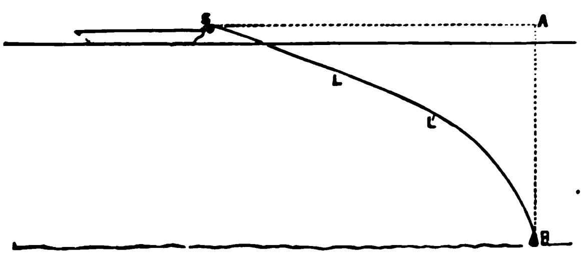
* The spun yarn stopper is to be seen in the accompanying perspective drawing, shewn as hanging ready for use.

† The Side Elevation shews the sounding wheel projecting over the taffrail in the position for paying out the wire: and the perspective drawing shews it as run inboard in the position for hauling up.

‡ In respect to the arrangement of framing for bearing the castor axle of the forked piece in which the castor wheel or pulley runs, the side elevation is purposely made to suggest an improvement from the arrangement actually existing in the machine shewn at the meeting, and represented in the perspective drawing. The improvement consists merely in lengthening the castor axle, and providing for it two bearings, instead of its having only one, as was the case in the machine shewn at the meeting, and as is exhibited in the perspective drawing from a photograph of the machine itself.

saving of time is effected: for in the ordinary process the hemp rope must be kept as nearly as possible up and down, until the whole length out does not exceed a few hundred fathoms.

Approximate soundings, of great use in ordinary navigation, may be obtained in depths of 200 fathoms, or less, with remarkable ease, without reducing the speed of the ship below five or six knots, even when the wire is being paid out. For this purpose let the weight fall direct from the wire wheel over the taffrail, with a brake-resistance of from five to ten pounds. The moment of its reaching the bottom is indicated by a sudden decrease in the speed of rotation of the wheel. The moment this is observed, a man standing at the wheel grasps it with his two hands, and stops it. Not more than three or four hundred fathoms of wire having run out, the hauling-in is easy. In following this process I have generally found it convenient to arm the lead with a proper mixture of tallow and wax, in the usual manner, to bring up specimens from the bottom. The actual depth is, of course, less than the length of wire run out. The difference, to be subtracted from the length of wire out to find the true depth, may be generally estimated with considerable accuracy after some experience. The estimation of it is assisted by considering that the true depth is always, as we see from the annexed diagram, greater than $l-a$ and less than $\sqrt{l^2-a^2}$, where l denotes the length of wire out,



$$\begin{aligned} l &= SLL'B \\ a &= SA \\ b &= AB \\ l &> \sqrt{(a^2+b^2)} \\ l &< (a+b) \\ \therefore b &< \sqrt{(l^2-a^2)} \\ b &> (l-a) \end{aligned}$$

FLYING SOUNDINGS.

and a the space travelled by the ship, diminished by the space travelled horizontally by the sinker during the time of its going to the bottom.

The contrast between the ease with which the wire and sinker are got on board from a depth of 200 fathoms by a single man, or by two men, in this process, and the labour of hauling in the ordinary deep-sea lead and line, by four or five men, when soundings are taken in the ordinary way from a ship going through the water at four or five knots in depths of from 30 to 60 fathoms, is remarkable. Professor Jenkin and I found this process of great value on board the

"Hooper," during the laying of the Western and Brazilian Telegraph Company's cables between Para, Pernambuco, Bahia, and Rio Janeiro. I am now having constructed, for the purposes of navigation, a small wire wheel of 12 inches diameter, to have 400 fathoms of piano-forte wire coiled on it, for flying soundings in depths of from 5 to 200 fathoms, without any reduction of the speed of the ship, or, at all events, without reducing it below five or six knots.

During the whole process of sounding, we are continually reminded of the original purpose of the wire by the sounds it gives out. A person of a musical ear can tell within a few pounds what pull is on the wire by the note it sounds in the length between the castor pulley at the stern and the haul-in drum, which is about five feet inboard of it.

Mr. James R. Napier said that there were some very ingenious and simple contrivances for overcoming difficulties about Sir William Thomson's sounding machine, as indeed there were about all his inventions. The two which struck him most were—1st, the application of a definite weight to the friction wheel, whereby almost the exact instant of the weight's reaching the bottom could be ascertained by the sudden stopping of the revolutions of the coil; and the other was, his method of preventing the compressing force of the wire from accumulating at each revolution, so as to crush the wheel.

MINUTES.

November 5, 1873.

THE Session of the Philosophical Society of Glasgow was opened this evening, Professor Grant, LL.D., the President, in the Chair.

Mr. John Boyd, Engineer, and Mr. Peter M'Intyre, were elected members of the Society.

The President delivered an Opening Address, for which, on the motion of Mr. James R. Napier, seconded by Dr. Fergus, he received the thanks of the Society.

November 19, 1873.

The Seventy-second Annual Meeting of the Philosophical Society of Glasgow, for the Election of Office-bearers and other business, was held this evening, Professor Grant, LL.D., the President, in the Chair.

The following were elected members of the Society, viz.:—

Dr. Eben. Watson, Professor of Institutes of Medicine in the Andersonian University, 1 Woodside Terrace; Dr. Joseph Coats, 33 Elmbank Street; Mr. James Watson, 2 Florentine Place, Hillhead; Dr. Strethall H. Wright, M.R.C.P.E., Barony Hospital and Asylum, Barnhill; Dr. John Ewan Brodie, C.M., 99 Douglas Street; Mr. D. C. M'Vail, Surgeon, 96 New City Road; Mr. Peter M'Nicol, M.A., 186 North Street; Mr. T. L. Patterson, Analytical Chemist, 29 Cathcart Street, Greenock.

The Secretary read the Council's Report on the State of the Society, which was approved of and ordered to be printed in the *Proceedings*.

REPORT OF THE COUNCIL ON THE STATE OF THE SOCIETY.

1. *State of the Membership.*—At the beginning of the Session of 1872-73, the number of Members on the roll of the Society was 533. In the course of the Session 61 new members were added

to the number, which, with two reinstated from the suspense list, give a total of 596. From this number there fall to be deducted—nine resigned, three left Glasgow and placed on suspense list, and eight dead, 20 in all—leaving a total on the Society's roll of 576 members. This is the greatest number ever reached by the Society, and it has to be noted, as an unexampled fact in its history, so far as is known, that not one of the members is in arrears of payment.

2. *The Proceedings.*—The printed *Proceedings* of the Society during the Session 1872-73 occupied 271 pages, forming the second and concluding part of the eighth volume, consisting of 506 pages.

On the evening of the Annual Meeting, Mr. Jas. R. Napier gave an account of the Livingstone Relief Expedition, *via* the Congo, from documents with which Mr. Young of Kelly had supplied him.

The second paper was "On Some Evidences as to the very early Use of Iron," by Mr. St. John Vincent Day; who also furnished the last paper of the Session—viz., "On the Past and Present of Iron Smelting." Dr. Stevenson Macadam of Edinburgh, by an arrangement with the Chemical Section, read a paper "On Flour Mill Fire-Explosions," illustrated by experiments. A note on this subject by the late Professor W. J. Macquorn Rankine, printed in the minutes, was his latest communication to the Society, and, through it, to the public. The next paper was by Mr. Jas. R. Napier, "On British Weights and Measures;" in the discussion of which Sir William Thomson took a prominent part. On a subsequent evening the subject was reviewed by Mr. Day. At the succeeding meeting Mr. Napier communicated a paper by Mr. E. L. Garbett, "On Numeral and Metral Systems." The subject of the "Purification of Water" was brought before the Society by Professor Bischof, of the Andersonian University. The next communication was by Professor Forbes, of the Andersonian University, "On the Transit of Venus in 1874." Mr. David Sandeman introduced the subject of "Technical Education," which was fully discussed by members of the Society.

The Chemical Section contributed a paper by Mr. Jas. Anderson, "On Volcanic Vapours of Mount Vesuvius;" and another by Mr. Wm. Henderson, "On the Decomposition of Sulphate of Potash by Nitrate of Soda."

From the Section of Sanitary and Social Economy were received a paper by Mr. William Miller, Banker, entitled, "Examination and Defence of the Principles enunciated by Mr. Lowe in his letter to the Chamber of Commerce, Glasgow, of the 20th December, 1872;"

also, a paper by Mr. Jas. Anderson, "On the Mint Bank Note of the Future;" and a communication by Mr. Stephen Mason on "The Bank Acts and the Rate of Discount."

The *Proceedings* contain reports of the business transacted by the Chemical Section and the Section of Sanitary and Social Economy. A paper by Dr. Robt. Bell, "On the Potato Disease," was read to the Society, but not printed in the *Proceedings.*

The Council have sanctioned a series of rules which the Committee on Papers have proposed for their guidance. As the Council has been enjoined by the Society to print and issue the *Proceedings* in the course of the Session, with the least possible delay after papers have been read before the Society, the attention of members who intend to contribute to the *Proceedings* of the present Session is respectfully directed to the two following rules:—

First, The Committee on Papers is to judge of the suitableness of communications offered to the Society, and to require that papers, or an abstract of them, be lodged in the hands of the Secretary ten days before the meeting of the Society when they are appointed to be read.

Third, No paper to be printed that is not left with the Secretary on the evening when it is read. The Committee to insist on all papers being thoroughly prepared for press before being sent to the printers, so as to avoid alterations in the proof sheets.

The Society is now entirely free of debt.

The Council have once more to acknowledge their obligations to their Finance Committee for the important services they have rendered to the Council in administering the Finance of the Society. The Council have recorded in their minutes their warmest thanks to Mr. Wm. R. W. Smith, one of the retiring members, for the painstaking attention he has given to this matter during the past three years in which he has held office.

Mr. Day read the Library Committee's Report on the Library, which was approved of, and ordered to be printed in the *Proceedings.*

Library Committee's Report.

With respect to the state of the Library, the Library Committee have to report the purchase of fifty-seven volumes and eight pamphlets, making the additions to the Library, in respect of purchase, sixty-five since the date of the last Report. In the same period the Library has received two hundred and twenty-four

donations of books, pamphlets, and parts, a number which your Committee believe to be unprecedented. Of these no less than one hundred and fourteen volumes and parts were presented from the Royal Observatory, Greenwich, by order of the Lords Commissioners of the Admiralty.

The Society exchanges publications with seventy-four different Societies and individuals, being an increase of four since last Session.

The binding of books and periodicals has been regularly kept up.

Mr. Mann, the Treasurer, gave in his Abstract of Account for Session 1872-73, which was approved of. It is as follows:—

Abstract of Treasurer's Account.

Session 1872-73.

Dr.

1872. Nov. 1.		
To Balances from last Session—		
In Union Bank of Scotland, ...	£14 4 10	
In Treasurer's hands, ...	2 5 3	
		£16 10 1
1873. Oct. 31.		
To Entry Money and Dues from 61 New Members, at 42s., ...	£128 2 0	
,, Annual Dues from 4 Original Members, at 5s.,	1 0 0	
,, Annual Dues from 517 Members, at 21s., .	542 17 0	
,, Annual Dues from 2 Members, for two years, .	4 4 0	
		676 3 0
,, Chemical Section.—7 Associates for 1871-72, at 5s., ...	£1 15 0	
36 Associates for 1872-73, at 5s., ...	9 0 0	
		10 15 0
,, Sanitary Section.—34 Associates for 1872-73, at 5s., . . .		8 10 0
,, Corporation of Glasgow, interest on "Exhibition Fund,"	£49 3 4	
,, Interest from Bank, ...	4 16 10	
		54 0 2
,, Catalogues sold, 28, at 1s., ...	£1 8 0	
,, *Proceedings* sold, ...	1 6 9	
		2 14 9
		£768 13 0

CR.

1873. Oct. 31.		
By Salaries and Wages,		£170 14 7
,, New Books and Binding,		123 15 3
,, Printing *Proceedings*, Circulars, &c.,		150 0 0
,, Postage and delivery of Circulars, &c.,		23 2 10½
,, Stationery,		3 2 0
,, Lithographing and Printing Plates for *Proceedings*,		10 14 0
,, Rents,		130 0 0
,, Insurance, Gas, Coal, Cleaning, &c.,		26 15 3
,, Petty Charges and Sundries,		1 9 11½
,, Subscription to Ray Society, 1873,	£1 1 0	
,, ,, Palæontographical Society, 1873,	1 1 0	
		2 2 0
,, Chemical Section.—Expenses per Treasurer of Section,		7 8 9
,, Sanitary Section.—Expenses per Secretary of Section,		10 12 3
,, Balances—		
In Union Bank,	£99 16 10	
In Treasurer's hands,	8 19 3	
		108 16 1
		£768 13 0

GLASGOW, *13th November, 1873.*—We, the Auditors appointed to examine the Treasurer's Accounts, have examined the same, of which the above is an Abstract, and found them correct, the Balance in Union Bank at 31st October last being Ninety-nine pounds sixteen shillings and ten pence sterling; and in Treasurer's hands, Eight pounds nineteen shillings and three pence.

(Signed) GEORGE WATSON.
ARCHD. ROBERTSON.

The Society then proceeded to the election of Office-bearers, in room of those retiring by rotation.

On the motion of the President, Professor Allen Thomson, M.D. was elected Vice-President.

On the motion of the President, Mr. St. John Vincent Day was re-elected Librarian, Mr. John Mann was re-elected Treasurer, and Mr. William Keddie was re-elected Secretary.

The following gentlemen were nominated to succeed the four retiring Members of Council, viz:—

Mr. Archibald Robertson, Mr. John Jex Long, Dr. Henry Muirhead, Mr. Robert Gray, Mr. James Deas, Mr. Sigismund Schuman, and Mr. John Ferguson.

Dr. Wallace and Mr. Wm. R. W. Smith were appointed Scrutineers of Votes.

Mr. Robertson, Mr. Long, Dr. Muirhead, and Mr. Gray, having the largest number of votes, were declared duly elected.

The following is the list of Office-bearers for the year 1873-74:—

President.

PROFESSOR ROBERT GRANT, M.A., LL.D., F.R.S.

Vice-Presidents.

PROFESSOR JOHN YOUNG, M.D., F.R.S.E.
PROFESSOR ALLEN THOMSON, M.D., F.R.S.

Librarian.

MR. ST. JOHN VINCENT DAY, C.E., F.R.S.E.

Treasurer.

MR. JOHN MANN, C.A.

Secretary.

MR. WILLIAM KEDDIE, F.R.S.E.

Other Members of Council.

DR. JAMES MORTON.	MR. ALEXANDER WHITELAW.
DR. ANDREW FERGUS.	MR. WILLIAM M'ADAM.
MR. DAVID ROWAN.	MR. ROBERT GRAY.
DR. JAMES BRYCE, M.A., F.G.S.	DR. HENRY MUIRHEAD.
MR. THOMAS CHAPMAN.	MR. JOHN JEX LONG.
DR. THOS. E. THORPE, F.R.S.E.	MR. ARCHIBALD ROBERTSON.

Mr. James Thomson, F.G.S., communicated to the Society the results of his investigations into the Corals of the Mountain Limestone, illustrated by plates by a new process.

The thanks of the Society were given to Mr. Thomson, on the motion of Mr. John Mayer, seconded by Mr. Wünsch, both of whom bore testimony to the industry, perseverance, and ingenuity shewn by Mr. Thomson in the prosecution of his researches, and in his original method of illustrating them.

Mr. James R. Napier exhibited a photograph of Mr. R. S. Newall's Telescope, which the President, who had seen the instrument, characterised as the most powerful achromatic refracting telescope in existence;—also, a photograph of the Moon, from the great Melbourne Telescope, by R. J. Ellery, Esq., F.R.S., Government Astronomer, Victoria.

December 3, 1873.—*The* PRESIDENT *in the Chair.*

The following were elected members of the Society, viz.:—

Mr. Robert S. Hannah, Merchant, 80 Buchanan Street; Mr. William C. Coghill, Printer and Publisher, 263 Argyle Street; Mr. William Henderson (Messrs. Henderson, Hogg, & Co.), 26 Renfield Street; Mr. Alex. Miller, Jun. (Messrs. Inglis & Wakefield), 74 Gordon Street; Mr. William Galloway, H.M. Inspector of Mines, 377 Sauchiehall Street; Mr. William Baxter, 14 Gibson Street, Hillhead; Mr. Andrew Erskine Muirhead, Cart Forge, Crossmyloof; Mr. Robert Sutherland, Merchant, 18 Berkeley Terrace.

Dr. James Finlayson read a paper, "On some Indications of a Daily Periodicity in the Vital Functions of Man."

In the discussion which followed, Dr. Muirhead, Dr. Eben. Watson, Dr. Morton, and Mr. Coleman took part.

December 17, 1873.—*The* PRESIDENT *in the Chair.*

The following were elected members of the Society:—

Mr. Alexander Stronach, Banker; Mr. Campbell Houston, Soap and Candle Manufacturer, Paisley and Glasgow, Renfrew Villa, Pollokshields; Mr. Walter Stewart Kennedy, Allanbank, Crosshill; Mr. Joseph Findlay, 25 Lynedoch Street; Mr. Robert Young, Provision Merchant, Castlehill, Pollokshields; Dr. Thomas M'Call Anderson, Professor of Practice of Medicine in Andersonian University, 14 Woodside Crescent; Mr. David Crawford, Jun., Manager, Barrowfield Printworks, Bridgeton; Mr. John L. Bruce, Architect, 137 West Regent Street.

The Committee on Papers having suggested the propriety of a discussion in the Society on the Sewage Question, at their request Dr. Fergus introduced the subject, and was followed by Dr. Wallace, Bailie Bain, Mr. Jas. R. Napier, Mr. Stanford, Dr. Dougall, Mr. Wm. R. W. Smith, and Mr. John Downie.

On the motion of Mr. Horatio K. Bromhead, the discussion was adjourned till next meeting.

The Society adjourned till the first Wednesday of January.

January 7, 1874.—*The* PRESIDENT *in the Chair.*

The following gentlemen were elected members, viz. :—

Mr. George P. Thomson, Engineer, 2 Newton Place; Dr. J. Simpson Cumming, 467 St. Vincent Street; Dr. Douglas Reid, Helensburgh; Mr. James Cleland Burns, Ochtertyre, Crieff; Mr. Robert Frew, Mining Engineer, 160 Hope Street.

The discussion on the Sewage Question, adjourned at last meeting, was resumed by Mr. Alex. Scott, who was followed by Mr. James Mactear, Dr. Robert Bell, Mr. John Downie, C.E., Mr. William Foulis, Gas Manager, Mr. Buchan, Plumber, Dr. Fergus, &c. A supplementary and explanatory statement by Dr. Wallace was read in his absence.

January 21, 1874.—*The* PRESIDENT *in the Chair.*

The following gentlemen were elected members, viz. :—

Mr. Malcolm M'Ewan, 23 St. Enoch Square; Mr. George Younger, Commission Merchant, 1 North Exchange Court; Mr. W. D. Bankier, Metal Broker, 31 St. Vincent Place; Mr. J. M. Macleish, Merchant, 10 Hamilton Drive, Hillhead; Mr. Donald M. Teacher, Merchant, 20 Park Circus; Mr. W. H. Rowan, Accountant, Clydeford, Rutherglen.

By an arrangement with the Chemical Section, Dr. Stevenson Macadam, F.R.S.E., of Edinburgh, delivered a lecture "On Water Supply," with illustrations.

On the motion of Mr. Stanford, President of the Chemical Section, the Society voted its warmest thanks to Dr. Macadam.

February 4, 1874.—In the absence of the President and Vice-Presidents, Dr. Fergus was called to the Chair.

The following gentlemen were elected members, viz :—

Mr. James Hunter, Timber Merchant, 19 Union Street; Dr. James Donaldson, Deputy Inspector-General of Hospitals, 8 Granby Terrace, Hillhead; Mr. Thomas Robertson, Accountant, 97 Union

Street; Mr. Andrew Carrick Robertson, Accountant, 116 St. Vincent Street.

Mr. Jas. R. Napier read a paper "On the Economy of Fuel in Domestic Arrangements."

February 18, 1874.—*The* PRESIDENT *in the Chair.*

The following were elected members of the Society, viz:—

James Thomson, LL.D., C.E., Professor of Engineering in the University of Glasgow; Mr. John Miller (Messrs. James Black & Co.), 23 Royal Exchange Square; Mr. James S. Higginbotham, 147 St. Vincent Street; Mr. John Hopkins, Wine Broker and Commission Merchant, 73 Gordon Street; Mr. J. Veitch Wilson, 116 St. Vincent Street; Mr. J. G. M'Arthur, 116 St. Vincent Street.

Professor James Thomson, LL.D., delivered a lecture "On the Gaseous, the Liquid, and the Solid States of Matter," illustrated by experiments.

March 4, 1874.—*The* PRESIDENT *in the Chair.*

Mr. James M'Creath, Mining Engineer, was elected a member of the Society.

The following notices of motion were given:—

Dr. Bryce.—"That the Society express its deep sorrow at the tidings of Dr. Livingstone's death, and communicate to the family of Dr. Livingstone an assurance of its sympathy; that a Committee be appointed to prepare a Minute, to be submitted to next meeting, and engrossed in the Minute-book of the Society, and that a copy of the same be transmitted to the family."

Mr. Jas. R. Napier.—1. "That the periodical *Proceedings* of the Society be issued as soon as possible to *all* Members of the Society, and to *all* societies or persons with whom the Society exchanges transactions, proceedings, journals, or papers."

2. "That the names and addresses of the Members of the Society be printed on the same size of paper as the *Proceedings*, and form part of them."

3. "That a printed copy of the Minutes of each Meeting of the

Society be sent to each Member, along with the notice calling the next Meeting."

A paper was read by Dr. Wallace, F.R.S.E., F.C.S., Gas Examiner for the City of Glasgow, "On the Economical Combustion of Gas."

In the discussion which followed, Mr. J. J. Coleman, Mr. Mackintosh, Mr. Foulis, Mr. Jas. R. Napier, &c., took part.

March 18, 1874.—*The* PRESIDENT *in the Chair.*

Agreeably to notice of motion given at last Meeting, Dr. Bryce moved,—"That the Society express its deep sorrow at the tidings of Dr. Livingstone's death, and communicate to the family of Dr. Livingstone an assurance of its sympathy; that a Committee be appointed to prepare a Minute to be submitted to next meeting, and engrossed in the Minute-book of the Society, and that a copy of the same be transmitted to the family."

The motion was seconded by Mr. Archibald Robertson.

Mr. Jas. R. Napier objected to the motion, on the ground of there being no positive evidence of the death of Dr. Livingstone.

After a short discussion, the motion was submitted to the Meeting, when twelve voted for and four against it.

Dr. Bryce stated that in the circumstances he considered it proper to withdraw the motion, which was accordingly done with the consent of the Society.

Mr. Jas. R. Napier having given notice of a motion,—"That the periodical *Proceedings* of the Society be issued as soon as possible to *all* Members of the Society, and to *all* societies or persons with whom the Society exchanges transactions, proceedings, journals, or papers,"—now proposed that it be limited for the present to the sending of the *Proceedings* periodically "to all societies or persons with whom the Society exchanges transactions, proceedings, journals, or papers;" leaving for future consideration that part of the motion relating to sending the periodical *Proceedings* "to all Members of the Society." This was agreed to without a vote.

It was also agreed to, on the motion of Mr. Jas. R. Napier,—due notice of the same having been given at last meeting,—"That the names and addresses of the Members of the Society be printed on the same size of paper as the *Proceedings*, and form part of them." And

"That a printed copy of the Minutes of each Meeting of the Society be sent to each Member, along with the notice calling the next Meeting."

Sir William Thomson explained a Method of Deep-Sea Sounding by Piano-forte Wire, which he illustrated by a model of the apparatus.

Sir William made a subsequent communication "On Improvements in the Mariner's Compass."

April 1, 1874.—*The* PRESIDENT *in the Chair.*

Mr. Alexander Moffatt, Steamship Agent, was elected a Member.

Mr. Jas. R. Napier gave notice of motion:—"That the Council be requested to take such steps as may be necessary for organising Section C, Physics, including Mechanics and Engineering, in terms of the IX. Section of the Constitution."

The Council gave notice of motion:—"That the Society add to its list of Honorary Members the following gentlemen, viz.:—

Lewis Dunbar Brodie Gordon, Esq., C.E., F.R.S.E., F.G.S., formerly Professor of Civil Engineering and Mechanics in the University of Glasgow; Robert Lewis John Ellery, Esq., F.R.A.S, Government Astronomer and Superintendent of Geodetic Survey of the Colony of Victoria, and President of the Royal Society of Victoria; Andrew C. Ramsay, LL.D., F.R.S., Director-General of the Geological Surveys of the United Kingdom; Joseph Dalton Hooker, M.D., F.R.S., Director of the Botanic Gardens at Kew, and President of the Royal Society of London; R. Angus Smith, Ph.D., F.R.S., F.C.S., Manchester."

The Secretary read a letter addressed to him by Mr. Chas. Eadie, intimating the death of his father, Mr. James Eadie, one of the original Members of the Society, in his 78th year.

Mr. Croudace's "Stellar Azimuth Dumb Compass" was exhibited and explained by Professor Grant.

Mr. Jas. R. Napier said that it was a very ingenious instrument, and that it gave, by very simple means, many more opportunities of finding the ship's position at night, than could be obtained from the sun by day. The plan of lighting the two extremities of the stellar bar, so as to enable its being placed in any direction, was excellent; and the means adopted for lighting

the lamp, however exposed the situation might be, could not be surpassed for simple efficiency.

Mr. Jas. R. Napier read a paper "On the Cubic Space and on the Volume of Air necessary for ensuring the Salubrity of Inhabited Places."

Dr. Thorpe, Mr. Alex. Scott, and others, made some remarks on the subject of the paper.

Mr. Jas. R. Napier read a paper "On the Effects of Loch Katrine Water on Galvanised Iron."

In the discussion which followed, Dr. Thorpe, Mr. Whitelaw, Mr. Mayer, &c., took part.

Mr. Symington exhibited and practically tested his "Patent Electric Fire Alarm;" also exhibited his "Patent Sewage Filter."

April 15, 1874.—*The* PRESIDENT *in the Chair.*

Mr. Jas. R. Napier moved—"That the Council be requested to take such steps as may be necessary for organising Section C, Physics, including Mechanics and Engineering, in terms of the IX. Section of the Constitution."

The motion was seconded by Dr. Bryce, but after some discussion was withdrawn.

The President, on the part of the Council, moved—"That the Society add to its list of Honorary Members the following gentlemen, viz.:—

Lewis Dunbar Brodie Gordon, Esq., C.E., F.R.S.E., F.G.S., formerly Professor of Civil Engineering and Mechanics in the University of Glasgow; Robert Lewis John Ellery, Esq., F.R.A.S., Government Astronomer and Superintendent of Geodetic Survey of the Colony of Victoria, and President of the Royal Society of Victoria; Andrew C. Ramsay, LL.D., F.R.S , Director-General of the Geological Surveys of the United Kingdom; Joseph Dalton Hooker, M.D., F.R.S., Director of the Botanic Gardens at Kew, and President of the Royal Society of London; R. Angus Smith, Ph.D., F.R.S., F.C.S., Manchester.

The motion was seconded by Mr. Jas. R. Napier, and unanimously agreed to.

Mr. John Ferguson, A.M., University Chemical Laboratory, read a paper "On some recent Classifications of the Elements."

In the discussion which followed, Dr. Thorpe, Mr. Whitelaw, Mr. Mayer, and Mr. Coleman took part.

April 29, 1874.—*The* PRESIDENT *in the Chair.*

Mr. James Hislop, Gas Manager, Maryhill Gas Works, was proposed as a Member by Mr. W. R. W. Smith, Mr. Robert R. Tatlock, and Mr. W. Keddie.—Ballot at opening of next Session.

The following Minute was given in and read:—

In terms of the intimation of date 25th April, 1874, inviting a meeting of members of the Society favourable to the formation of the Section of Physics, including Mechanics and Engineering, to be held in the Library of the Society on Tuesday Evening, 28th inst., the members met in the Library, and on the motion of Mr. Jas. R. Napier, seconded by Mr. Alexander Scott, Mr. Nathaniel Dunlop was called to the Chair, when, after full discussion, it was resolved, on the motion of Mr. Napier, seconded by Mr. Thomas M. Barr, C.E., that Section C (Rule IX. of Constitution) be now constituted.

It was also resolved that at the next meeting of the general Society, to be held on Wednesday, 29th instant, the Society be invited to recognise the formation and existence of the Section as an integral portion of the Society.

The following office-bearers were elected by the meeting (*pro tem.*):—

Mr. JAMES R. NAPIER, *Chairman.*
Mr. JAMES DICKSON, *Secretary.*

(Signed) NATHANIEL DUNLOP,
Chairman.

GLASGOW, *28th April, 1874.*

The President, in name of the Society, recognised the formation and existence of Section C.

The following reports were given in and read:—

CHEMICAL SECTION.

The Secretary is glad to be able to report, that although the number of papers at the meetings is fewer this Session, some of them have been of a very interesting and important character.

Only one new associate has been enrolled during the Session, but otherwise the Section is in a satisfactory condition. Some difficulty is experienced, however, from the fact that many of the original associates are located in distant parts of the country, and from an apparently increasing disposition on the part of members to read their papers at the Society's meetings.

ROBERT R. TATLOCK,
Secretary of Section.

Sanitary and Social Economy Section.

The Council have to report another active Session.

The following is an abstract of the proceedings, viz. :—

1st *Meeting*.—Inaugural Address of the Session by the President, Dr. Fergus, "On the Sanitary Solution of the Sewage Question."

2nd *Meeting*.—Paper by Mr. Peter Aitken on his "Gas-heating and Cooking Apparatus."

3rd *Meeting*.—Paper by Mr. Henry Murray, Honorary Secretary of the Scottish National Toll Association, "On Road Reform and the Abolition of Tolls."

4th *Meeting*.—Abstract of and discussion on paper by Mr. Jas. R. Napier, read by him before the Society, "On Economy of Fuel in Domestic Arrangements."

5th *Meeting*.—Abstract of and discussion on paper by Dr. Wallace, read by him before the Society, "On the Economical Combustion of Coal Gas."

6th *Meeting*.—Paper by Mr. Alexander Scott, "On a System of Decimal Weights, Measures, and Coinage for this Country."

7th *Meeting*.—Communication from Mr. Alexander Scott, "On the Application of Nessler's Ammonia Test for the Detection of Organic Impurities in Potable Water;" and from Mr. William M'Adam, "On a Simple and Secure Method of Collecting Tramway and other Fares."

The number of associates is now thirty-seven, shewing an increase of three during the Session.

The present Members of Council are as follows, viz. :—

Dr. Andrew Fergus, *President*.
Mr. W. R. W. Smith, *Vice-President*.
Mr. William M'Adam, *Vice-President*.

Mr. D. G. Hoey, C.A.	Mr. Stephen Mason.
Dr. Robert Renfrew.	Mr. Alexander Scott.
Dr. John M'Intyre.	Dr. James B. Russell.
Mr. Arthur Herriot.	Mr. William Melvin.

Mr. T. W. Watson.

Mr. Gavin Irving Dickson, *Secretary*.

Reported by GAVIN IRVING DICKSON,
Secretary of Section.

Mr. Jas. R. Napier stated that having been allowed by the Executrix of the late Professor Macquorn Rankine, to dispose of some of the books belonging to him, he wished to offer to the acceptance of the Society for its Library, a number of books and pamphlets, a list of which he now read.

The thanks of the Society were voted to the Donor, and also to Mr. Napier.

Mr. Napier presented from William Froude, Esq., F.R.S., a copy of his Report on "Experiments for the Determination of the Resistance of a Full-sized Ship at Various Speeds, by Trials with H.M.S. 'Greyhound.'"—Thanks voted.

On the motion of Mr. James Thomson, it was remitted to the Council to watch any proceedings which might be taken, consequent on a recent bequest for the institution of a Free Library, and to co-operate with the Municipal Corporation and other public bodies, with the view of establishing a Free Museum in conjunction with a Free Library.

Dr. Thorpe delivered an experimental Lecture "On the Measurement of the Chemical Action of Sunlight;" and exhibited and described Roscoe's new Automatic Photometer.

This being the closing meeting of the Session, the Society, on the motion of Mr. W. R. W. Smith, voted its warmest thanks to Professor Grant, for his valuable services as President during the Session.

ADDITIONS TO THE LIBRARY.

Donations.	Presented by	
Statistics of the Colony of Victoria, .	Regist.-Gen., Victoria.	9 Parts.
Transactions of the Society of Biblical Archæology, ...	The Society.	1 Vol.
On Deducing the Parallax of Mars, and thence that of the Sun, . . .	S. M. Drach, Esq.	1 Pamphlet.
On the Circle-area and Heptagon Chord,	,,	1 ,,
An Easy General Rule for Filling up all Magic Squares, ...	,,	1 ,,
Deductions from Mr. Glaisher's "Meteorological Corrections," . . .	,,	1 ,,
Transactions of the Geological Society of Glasgow, 1873, ...	The Society.	1 Part.
Memoires de la Société des Sciences de Bordeaux, ...	The Society.	1 ,,
Proceedings of the California Academy of Sciences, ...	A. Kellogg, Esq.	2 ,,
National Importance of Scientific Research, ...	G. Gore, Esq., F.R.S.	1 Pamphlet.
Contributions to the Study of the Entomostraca, ...	D. Robertson, Esq.	1 ,,
Canadian Entomologist, . . .	E. B. Reed, Esq.	3 Parts.
Journal of the Anthropological Institute of Great Britain and Ireland, . .	The Society.	1 ,,
The U. S. Sanitary Commission in the Valley of the Mississippi, 1871, . .	Dr. J. S. Newberry.	1 Vol.
Proceedings of the Literary and Philosophical Society of Liverpool, . .	The Society.	3 ,,
Proceedings of the Cleveland Institution of Engineers, 1873, ...	The Institution.	5 Parts.
The Report of the Birkenhead Literary and Scientific Society, 1872-73, . .	The Society.	1 ,,
Memoirs of the Geological Survey of India—Palæontologia Indica, 1873, .	The Survey.	2 ,,
Records of the Geological Survey of India, 1873, ...	,,	4 ,,
Memoirs of the Geological Survey of India, 1873,—Geology of Madras, .	,,	2 ,,

DONATIONS.	Presented by	
Catalogue of Stars Observed at the United States Naval Observatory during the Years 1845 to 1871, . .	B. F. Sands, Esq.	1 Vol.
Results of Observations made at the U.S. Naval Observatory with the Transit Instrument and Mural Circle, in the Years 1853 to 1860, inclusive, . .	,,	1 ,,
Zones of Stars Observed at the U. S. Naval Observatory with the Mural Circle, in the Years 1846, 1847, 1848, and 1849, ...	,,	1 ,,
Astronomical and Meteorological Observations made during the Year 1870, at the U.S. Naval Observatory, .	,,	1 ,,
On the Right Ascension of the Equatorial Fundamental Stars and the Corrections necessary to Reduce the Right Ascensions of Different Catalogues to a near Homogeneous System. By Simon Newcomb. 1872. . .	,,	1 Part.
Proceedings of the Royal Society of Edinburgh, ...	The Society.	1 ,,
Inaugural Ceremonies in Honour of the Opening of Fountain Gardens, Paisley,	Phil. Soc., Paisley.	1 Vol.
Proceedings of the Geological Society, Liverpool, 1872-73, ...	The Society.	1 Part
Transactions of the North of England Institute of Mining and Mechanical Engineers, 1872-73, ...	The Institute.	2 Vols.
Results of an Experimental Inquiry into the Mechanical Properties of Steel of Different Degrees of Hardness, and under various Conditions, Manufactured by Christian Aspelin, Esq., Westanfors and Fagersta Works, Sweden. 1873. By David Kirkaldy,	D. Kirkaldy, Esq.	1 ,,
Transactions of the Society of Engineers, 1873, ...	G. W. Harris, Esq.,	2 ,,
Transactions and Proceedings of the New Zealand Institute for 1869, 1870, 1871 and 1872, ...	James Hector, M.D.	4 ,,
Catalogue of the Birds of New Zealand, with Diagnoses of the Species. By Frederick W. Hutton, F.G.S., 1871. Notes on the Edible Fishes of New Zealand. By James Hector, M.D., F.R.S. Catalogue of the Echinodermata of New Zealand, with Diagnoses		

DONATIONS.	Presented by	
of the Species. By Frederick W. Hutton, F.G.S., 1872, . . .	James Hector, M.D.	1 Vol.
Geological Survey of New Zealand—Reports of Geological Explorations during 1870-71. By James Hector, M.D., F.R.S., ...	,,	1 ,,
Transactions of the Botanical Society of Edinburgh, ...	The Society.	1 Part.
Transactions of the Geological Society of Glasgow. The Silurian Brachiopoda of the Pentland Hills. By Thomas Davidson, F.R.S., ...	The Society.	1 ,,
Forhandlinger i Videnskabs-Selskabet i Christiania, 1872, ...	Univ. of Christiania.	1 Vol.
Christiania Omegns Phanerogamer og Bregner Med Angivelse af Deres Udbredelse samt en Indledning om Vegetationens Afhængighed af Underlaget. Af A. Blytt, Conservator, 1870,	,,	1 Pamphlet.
Beretning om den Almindelige Udftilling for Tromso Stift, 1872, . .	,,	1 ,,
Joh. Storm. De Romanske Sprog og Folk, 1871, ...	,,	1 ,,
Carcinologiske Bidrag til Norges Fauna. Af G. O. Sars, 1870, ...	,,	2 Parts.
Cantate ved det Kongelige Norske Frederiks Universitets Mindefest for Hans Majestaet Kong Carl den 19de November, 1872, ...	,,	1 Pamphlet.
The River Clyde. By James Deas, M. Inst. C.E. With an Abstract of the Discussion upon the Paper. Edited by James Forrest, Assoc. Inst. C.E., Secretary, 1873, ...	James Deas, Esq.	1 ,,
Proceedings of the South Wales Institute of Engineers, ...	The Institute.	2 Parts.
Greenwich Observations for 1871, . .	Royal Observatory, Greenwich.	1 Vol.
Results of Astronomical Observations for 1871, ...	,,	1 Part.
Greenwich Magnetical Results for 1871,	,,	1 ,,
History and Description of the Water Telescope of the Royal Observatory, Greenwich, ...	,,	1 ,,
Journal of the Franklin Institute, 1874,	The Institute.	2 ,,
Final Report of the Exploration Committee of the Royal Society of Victoria for 1863, ...	The Society.	1 ,,

DONATIONS.	Presented by	
Principles of Dynamics. By John W. Nystrom, C.E., Philadelphia, 1874, .	John W. Nystrom, Esq.	1 Pamphlet.
Verhandelingen der Koninklijke Akademie van Wetenschappen, 1873, .	Amsterdam Society.	1 Part.
Jaarboek van de Koninklijke Akademie van Wetenschappen, 1872, . .	,,	1 ,,
Verslagen en Mededeelingen der Koninklijke Akademie van Wetenschappen, 1873, ...	,,	2 Vols.
Processen Verbaal Koninklijke Akademie van Wetenschappen te Amsterdam, 1872-73, ...	,,	1 Part.
Annual Report on the Health of the City for the Year 1872. By James B. Russell, M.D. And on the Sanitary Department for the Year ending 30th April, 1873. By K. M. Macleod, .	K. M. Macleod, Esq.	1 Pamphlet.
The Calendar of the Pharmaceutical Society of Great Britain for 1874, .	The Society.	1 Part.
Proceedings of the Philadelphia Academy of Natural Sciences for 1872, .	The Academy.	3 ,,
Observations of Shooting Stars in the Years 1869, 1870, 1871, with Two Plates. By Captain George Lyon Tupman, Royal Marine Artillery, 1874,	Capt. G. L. Tupman.	1 Pamphlet.
Quantitative Chemical Analysis. By T. E. Thorpe, Ph.D., F.R.S.E. 12mo, 1873, ...	Dr. T. E. Thorpe.	1 Vol.
Qualitative Chemical Analysis and Laboratory Practice. By T. E. Thorpe, Ph.D., F.R.S.E., and M. M. Pattison Muir, F.R.S.E. 12mo, 1873, . .	From the Authors.	1 ,,
Memoirs of the Literary and Philosophical Society of Manchester, . . .	The Society.	1 ,,
Proceedings of the Literary and Philosophical Society of Manchester, . .	The Society.	3 ,,

---

DONATION FROM THE EXECUTRIX OF THE LATE PROFESSOR WILLIAM J. MACQUORN RANKINE, C.E., LL.D., F.R.S., Professor of Civil Engineering and Mechanics in the University of Glasgow.

Library of Useful Knowledge, Lives of Eminent Persons. 8vo, 1833, . .	...	1 Vol.
Traité de Chimie Eléméntaire Théorique et Pratique, suivi d'un Essai sur la Philosophie Chimique et d'un Précis		

DONATION.		
sur L'Analyse. Par M. le Baron L. J. Thenard, 8vo, 1836, ...	...	2 Vols.
Éxposition Universelle a Londres en 1862. Notices sur les Modèles, Cartes et Dessins Relatifs aux Travaux Publics. Paris, 8vo, 1862, ...	...	1 ,,
Elements of Theoretical Mechanics; being the Substance of a Course of Lectures on Statics and Dynamics. By Thomas Jackson, LL.D., 8vo, 1827,	...	1 ,,
Specifications relating to Marine Propulsion, 16mo, 1858, ...	...	1 Part.
Specifications relating to Drain Tiles and Pipes, 16mo, 1857, ...	...	1 ,,
Specifications relating to Steam Culture, 16mo, 1858, ...	...	1 ,,
Specifications relating to Aids to Locomotion, 16mo, 1858, ...	...	1 ,,
Report of the Committee on Meteorological Department of the Board of Health, London, 1866, . . .	...	1 ,,
Report on various Experiments carried out under the Direction of the Ordnance Select Committee, relative to the Penetration of Iron Armour Plates by Steel Shot. London, 1866, . .	...	1 ,,
Navy Turret-Ship—Copy of Reports of the Committee of Naval Officers appointed to Examine the Design of a Turret-Ship, designed by Captain Cowper Coles, 1866, ...	...	1 ,,
Report Scottish Universities Commission, 1863, ...	...	1 ,,
Report of the Commissioners appointed to Inquire into the Application of Iron to Railway Structures, 1849, .	...	1 ,,
Plans Referred to in the Report of the Commissioners appointed to Inquire into the Application of Iron to Railway Structures, 1849, . . .	...	1 ,,
Report of the General Board of Health on the Supply of Water to the Metropolis, ...	...	5 ,,
Report of the General Board of Health on the Measures Adopted for the Execution of the Nuisance Removal and Diseases Prevention Act and the Public Health Act, up to July, 1849,	...	1 ,,

DONATION.

Relatorio do Commissario Regio junto à Commissão Imperial da Exposição Universal de Paris. 8vo. Lisboa, 1857, ...	...	4 Vols.
Practical Prevention of Dry Rot in Timber. By Professor Faraday, F.R.S., &c., 1836, ...	...	1 Pamphlet.
Euclid at Fault: Letter to James Dalton Hooker, Esq., F.R.S., D.C.L. By James Smith, Esq., Liverpool, 1868, .	...	1 ,,
A Lecture on the Preservation of Timber by Kyan's Patent for Preventing Dry Rot. By Dr. Birkbeck, 1834, .	...	1 ,,
Report on the Water Supply of Rutherglen. By W. J. Macquorn Rankine, for self and John Thomson, 1852, .	...	1 ,,
Six Lectures on the Wave Theory of Light. By the Rev. H. Lloyd, M.A., F.R.S., &c., 1836, ...	...	1 ,,
On the Nature of the Force by which Bodies are Repelled from the Poles of a Magnet; to which is Prefixed an Account of some Experiments on Molecular Influences. By John Tyndall, Ph.D., F.R.S., &c., 1855, . .	...	1 ,,
An Essay on the Theory and Practice of Setting out Railway Curves. By William Hill, 1847, ...	...	1 ,,
The Advantages of Tubular Drainage, as compared with Brick Sewers, in their Application to Houses and Cities. By John Thomson, C.E., 1852, . .	...	1 ,,
On the Relations Existing between the Dimensions and Distances of the Sun, Moon, and Earth. By James Smith, Esq., 1864, ...	...	1 ,,
A Letter Addressed to Nicholas Wood, Esq., on that Portion of Chapter IX. of his Treatise on Railroads, entitled "Comparative Performances of Motive Power on Canals and Railroads." By Thomas Graham, Esq., . .	...	1 ,,
On the Application of Hydraulic Buffers to Prevent the Destructive Effects of Railway Collisions. By Colonel H. Clerk, R.A., F.R.S. Woolwich, 1868,	...	1 ,,
On some of the Results obtained at the British Colonial Magnetic Observa-		

Donation.		
tories. By Colonel Edward Sabine, R.A., V.P.R.S., General Secretary, 26th September, 1854, . . .	...	1 Pamphlet.
On Vital Force, according to Age, and the "English Life Table." By Thomas Rowe Edmonds, B.A., Cantab., 1869,	...	1 ,,
On a Scale of Geometrical Equivalents for Engineering and other Purposes. By Charles Holtzapffel, 1838, . .	...	1 ,,
Life and the Equivalence of Force. By J. Drysdale, M.D. No date, . .	...	1 ,,
Two Essays on Radiant Heat, in Connection with the more Recent Discoveries; being Exercises written for the Class of Natural Philosophy in the University of Edinburgh. By Thomas Chalmers and Daniel R. Haldane, 1842,	...	1 ,,
A New Theory of the Steam Engine, and the Mode of Calculation, by means of it, of the Effective Power, &c., of every kind of Steam Engine, Stationary or Locomotive. By the Chevalier G. De Pambour, 1838, .	...	1 ,,
Plans for the Improvement of the Port of Leith; with Observations on the Tidal Currents. By John Milne. Second Edition, 1835, ...	...	1 ,,
Elements of the Economy of Nature. By J. G. Macvicar, D.D. Second Edition, 1856, ...	...	1 ,,
The Cambridge and Dublin Mathematical Journal. Edited by W. Thomson, M.A., F.R.S.E. No. XXV. Cambridge, 1851, ...	...	1 ,,
An Essay to show that Petroleum may be used with Advantage in Manufacturing Operations, for the Purpose of Heating Steam Boilers, and Generating Steam. By D. Bodde, Notary Public at Batavia. No date, . .	...	1 ,,
Notice sur la Transmission Télodynamique. Short Notice of the Telodynamic Transmission of Motive Power. Par C. F. Hirn. Colmar, 1862, .	...	1 ,,
Reports on Experiments made with the Bashforth Chronograph, to determine the Resistance of the Air to the Motion of Projectiles, 1865-1870. 1870,	...	1 ,,

DONATION.

A Treatise containing the Results of Numerous Experiments on the Preservation of Timber from Premature Decay, &c. By Wm. Chapman. 1817, ...	1 Pamphlet.
Scientific Memoirs. Edited by Richard Taylor, F.S.A. 1836-37, ...	3 Parts.
Reports on the Paris Universal Exhibition, Part I. 1856, ...	1 ,,
Austria at the International Exhibition of 1862, By Professor Dr. Jas. Arenstein. Printed on Indian-corn Paper, ...	1 ,,
International Exhibition of 1862. Official Catalogue of Industrial Department. (Professor Rankine's Working Copy as a Juror.)	1 Pamphlet.
International Exhibition Industrial Catalogue, British, 1862, ...	1 Part.
International Exhibition Industrial Department, 1862, ...	1 ,,
International Exhibition Fine Art Department, 1862, ...	1 ,,
Exposition Universelle de 1862 a Londres. Section Française. Catalogue Officiel des Produits de l'Empire Français, ...	1 ,,
Memoirs of the Geological Survey of Great Britain and the Museum of Practical Geology. Mineral Statistics, &c., for 1866. By R. Hunt, F.R.S., 1867, ...	1 ,,
Catalogue of Type Specimens of Fossil Fishes in the Collection of Sir Philip Egerton, Bart., M.P., at Oulton Park. 1869, 8vo, ...	1 Pamphlet.
Proceedings of Royal Society of Van Diemen's Land. Vol III., Part 1. Tasmania, 1855, ...	1 Part.
Special-Catalog der Gewerblichen Ausstellung des Zollvereins, Herausgegeben von den Commissarien der Zollvereins-Regierungen. Berlin, 1862, ...	1 ,,
Notice Théorique et Pratique sur l'Injecteur Automoteur, Breveté, propre a l'Alimentation des Chaudières et Vapeur et a l'Elevation de l'Eau. Par M. H. Giffard, 1861, ...	1 ,,
Die Schiebersteuerungen. Mit Besonderer Berücksichtigung der Steuer-	

DONATION.		
ungen bei Locomotiven. Von Dr. Gustav Zeuner. Freiberg, 1858, .	...	1 Part.
On the Change of Refrangibility of Light. By G. G. Stokes, 1853, . . .	...	1 ,,
On the Unconscious Activity of the Brain. By W. B. Carpenter, 1868, .	...	1 ,,

---

BOOKS BOUGHT.

Principles of Psychology. By Herbert Spencer. Second Edition. 8vo. 1872.

The Annual Register: A Review of Public Events at Home and Abroad, for the Year 1872. 8vo. 1873.

The Scottish Gaël; or, Celtic Manners, as Preserved among the Highlanders. By James Logan, Fellow of the Society of Antiquaries of Scotland. 2 vols. 8vo. 1831.

Essai Géologique sur l'Ecosse. Par A. Boué. 8vo. No date.

Journal of the Royal Geographical Society for 1872.

Zoological Record. Edited by Alfred Brown, M.A., F.R.S. 1 vol. 8vo. 1873.

Six Lectures on Light, delivered in America in 1872–1873. By John Tyndall, LL.D., F.R.S. 8vo. 1873.

Journey Across South America, from the Pacific Ocean to the Atlantic Ocean. By Paul Macroy. 1872.

Prodromus Systematis Naturalis Regni Vegetabilis. Editore et pro parte auctore Alphonso de Candolle. Pars Decima Septima. 1873.

An Architect's Note-Book in Spain, principally Illustrating the Domestic Architecture of that Country. By M. Digby Wyatt, M.A., Professor of the Arts in the University of Cambridge, &c. 4to. 1872.

Contributions to Solar Physics: A Popular Account of Inquiries into the Physical Constitution of the Sun, &c. By J. Norman Lockyer, F.R.S. 8vo. 1874.

Sanitary Engineering: A Guide to the Construction of Works of Sewerage and House Drainage. By Baldwin Latham, C.E., M. Inst. C.E. 8vo. 1873.

History of the Mathematical Theories of Attraction and the Figure of the Earth, from the Time of Newton to that of Laplace. By J. Todhunter, M.A., F.R.S. 2 vols. 8vo. 1873.

Statesman's Year-Book: Handbook for Politicians and Merchants for the Year 1874. By Frederick Martin. 12mo.

Report of the British Association for the Advancement of Science for the Year 1872. 8vo. 1873.

Studies of Blast Furnace Phenomena. By M. L. Gruner; translated with the Author's sanction; with an Appendix. By L. D. B. Gordon, F.R.S.E., F.G.S. 8vo. 1873.

Animal Locomotion; or, Walking, Swimming, and Flying; with a Dissertation on Aëronautics. By J. Bell Pettigrew, M.D., F.R.S., F.R.S.E., F.R.C.P.E. 1 vol. 12mo. 1873.

The Great Ice Age, and its Relation to the Antiquity of Man. By James Geikie, F.R.S.E., F.G.S. 1 vol. 8vo. London, 1874.

Heart of Africa: Three Years' Travels and Adventures in the Unexplored Regions of Central Africa, from 1866 to 1871. By George Schweinfurth. Translated by Ellen E. Frewer. 2 vols. 8vo. London, 1873.

Etruscan Researches. By Isaac Taylor, M.A., Vicar of Holy Trinity, Twickenham. 1 vol. 8vo. London, 1874.

An Art Tour to Northern Capitals of Europe. By J. Beavington Atkinson. 8vo. London, 1873.

Manual of Public Health, for the use of Local Authorities, Medical Officers of Health, and others. By W. H. Michael, F.C.S.; W. H. Corfield, M.A., M.D., Oxon.; and J. A. Wanklyn, M.R.C.S. Edited by Ernest Hart. 1 vol. 8vo. London, 1874.

Illustrations of the Botany and other Branches of the Natural History of the Himalayan Mountains, and of the Flora of Cashmere. By J. Forbes Royle, M.D., V.P.R.S. 2 vols. 4to. London, 1839.

Whaling Cruise to Baffin's Bay and the Gulf of Boothia, and an Account of the Rescue of the Crew of the "Polaris." By Albert Hastings Markham, F.R.G.S., Commander, Royal Navy. 8vo. 1874.

Two Years in Peru, with Explorations of its Antiquities. By Thomas J. Hutchinson, F.R.G.S., F.R.S.L., M.A.S. 2 vols. 8vo. London, 1873.

Works in Iron, Bridge and Roof Structures. By Ewing Matheson, of the Firm of Andrew Handyside & Co., Engineers, Derby and London. 1 vol. 8vo. London, 1873.

Naturalist in Nicaragua: A Narrative of a Residence at the Gold Mines of Chontales; Journeys in the Savannahs and Forests, with Observations on Animals and Plants in Reference to the Theory of Evolution of Living Forms. By Thomas Belt, F.G.S. 8vo. London, 1874.

Elements of Mineralogy, containing a General Introduction to the Science; with Descriptions of the Species. By James Nicol, F.R.S.E., F.G.S. Second Edition. 8vo. Edinburgh, 1873.

Palæontographical Society. 5 Parts.

Philosophical Transactions of the Royal Society of London. Part 2nd of Vol. 161; and Part 1st of Vol. 162.

Book added to Architectural Library—

L'Ornement Polychrome, 50 Plates in Colours. M. A. Racinet. Folio. 1873. 2 vols.

LIST OF WEEKLY, MONTHLY, AND QUARTERLY PERIODICALS RECEIVED IN THE PHILOSOPHICAL SOCIETY'S LIBRARY.

WEEKLY.

Iron.
Nature.
Builder.
Engineer.
Architect.
Athenæum.
Engineering.
Building News.
British Architect.
Les Mondes.
Comptes Rendus.
Chemical News.
Notes and Queries.
Annales Industrielles.
Polytechnisches Journal.
Pharmaceutical Journal.
Journal of the Society of Arts.

MONTHLY.

Annalen der Chemie und Pharmacie.
Annales de Chimie et de Physique.
Annalen der Physik und Chemie.
Journal de Pharmacie et de Chimie.
Annales des Ponts et Chaussees.
Journal fur Praktische Chemie.
Journal of the Chemical Society.
Journal of Botany.
Monthly Microscopical Journal.
Geological Magazine.
American Journal of Science and Art.
The Country Gentleman's Magazine.
Monatsbericht der Königlich Preussischen Akademie der Wissenschaften zu Berlin.
Abstracts of the Proceedings of the Geological Society of London.
Monthly Notices of the Royal Astronomical Society.
London, Edinburgh, and Dublin Philosophical Magazine.
Annals and Magazine of Natural History.

QUARTERLY.

Bulletin de la Société Chimique de Paris.
Journal of the Iron and Steel Institute.
Journal of the Statistical Society.
Journal of Anthropology.
Quarterly Journal of Science.
Quarterly Journal of Microscopical Science.
Quarterly Journal of Geological Society.
Annales des Mines.
The Ibis, Quarterly Journal of Ornithology.

PHILOSOPHICAL SOCIETY OF GLASGOW. EXCHANGE WITH OTHER SOCIETIES, &c.

Academy of Science, ...	Missouri.
Academy of Science, ...	Philadelphia.
American Philosophical Society, ...	,,
American Academy, ...	Boston.

American Institute,	New York.
Boston Society,	Boston.
Boston Natural History Society,	,,
Berwickshire Naturalist's Club,	Alnwick.
Canadian Institute,	Canada.
California Academy,	California.
Commissioners of Patents,	Washington.
Franklin Institute,	Philadelphia.
Geological Survey Office,	Calcutta.
Historic Society,	Quebec.
Institution of Mechanical Engineers,	Birmingham.
Lyceum of Natural History,	New York.
Midland Institute of Mining Engineers,	Barnsley.
North of England Institute of Mining Engineers,	Newcastle-on-Tyne.
Natural History Society,	Portland, Maine.
New York Agricultural Society,	New York.
National Academy,	Washington.
Pharmaceutical Society,	Philadelphia.
Professor J. D. Dana,	Connecticut.
Professor E. Loomis,	,,
Professor J. Henry—National Observatory,	Washington.
Royal Academy of Science,	Berlin.
,, ,, ,,	Stockholm.
,, ,, ,,	St. Louis.
,, ,, ,,	Brussels.
,, ,, ,,	Amsterdam.
,, Society of Victoria,	Melbourne.
,, Institute of Lombardy,	Milan.
,, Geographical Society,	Vienna.
,, Institution of Cornwall,	Truro.
Smithsonian Institution,	Washington.
Society of Physical Sciences,	Bordeaux.
United States Observatory,	Washington.
,, ,, Survey,	,,
University of Christiania,	Christiania.
J. Hoüel—La Société des Sciences Physique et Naturelles,	Bordeaux.
William H. Archer, Registrar-General,	Melbourne.
C. J. Matthes, of the Royal Academy,	Amsterdam.
E. B. Reed, Barrister-at-Law, London,	Ontario.
W. R. Couper, Secretary of the Society of Biblical Archæology,	London.
Alfred Coleman—Odontological Society,	,,
James Hector, M.D.—New Zealand Institute,	New Zealand.
Alfred Brown—Literary and Philosophical Society,	Liverpool.
Dr. J. M. Currie—Orleans County Society of Natural Sciences,	Vermont.
Charles Gilbert, Publisher of "Engineering,"	London.
S. W. Kershaw, Royal Institute of British Architects,	,,
Scottish Meteorological Society,	Edinburgh.

Botanical Society of Edinburgh, ...	Edinburgh.
Royal Society of Edinburgh, ...	,,
Royal Physical Society of Edinburgh, ...	,,
Royal Scottish Society of Arts, ...	,,
Royal Society of London, ...	London.
Chemical Society, ...	,,
Society of Arts, ...	,,
Pharmaceutical Society, ...	,,
Photographic Society, ...	,,
Statistical Society, ...	,,
Royal Institution of Great Britain, ...	,,
Anthropological Society, ...	,,
Historic Society of Lancashire and Cheshire, . . .	Liverpool.
Geological Society of Liverpool, ...	,,
South Wales Institute of Engineers, ...	Swansea.
Philosophical Society of Cambridge, ...	Cambridge.
Literary and Philosophical Society of Manchester, . .	Manchester.
Royal Cornwall Polytechnic Society, ...	Falmouth.
Cleveland Institution of Engineers, ...	Middlesborough.
Literary and Philosophical Society of Leeds, . . .	Leeds.

ERRATUM.

In page 12, line 27 from top, *for* "either units" *read* "ether units."

LIST OF MEMBERS.

HONORARY MEMBERS.

FOREIGN.

Elected in 1860—M. Chevreul, Paris.
— 1860—M. Dumas, Paris.
— 1860—Professor H. Helmholtz, Heidelberg.
— 1860—Professor Albert Kölliker, Wurtzburg.
— 1860—M. Le Verrier, Paris.
— 1860—Professor W. Weber, Leipzig.
— 1874—Robert Lewis John Ellery, Esq., Victoria.

AMERICAN.

Elected in 1860—Prof. James D. Dana, Yale College, Connecticut.
— 1860—Prof. Joseph Henry, Secretary to Smithsonian Institution, Washington.
— 1860—Professor Loomis, New York.

BRITISH.

Elected in 1849—John J. Griffin, Esq., London.
— 1850—Prof. Balfour, Edinburgh.
— 1860—Dr. J. P. Joule, Manchester.
— 1860—Gen. Sabine, R.A., London.
— 1874—Lewis D. B. Gordon, Esq., London.
— 1874—Prof. A. C. Ramsay, London.
— 1874—Dr. J. D. Hooker, London.
— 1874—Dr. R. A. Smith, Manchester.

ORDINARY MEMBERS.

Buchanan, Andrew, M.D., Prof. of Institutes of Medicine in the University of Glasgow, 186 Bath street.
Hart, Robert, Cessnock Park, Govan road.
Stewart, John, Annat Lodge, Helensburgh.
(*The above are Original Members.*)
Adamson, John, Clayton Cottage, Westercraigs, Dennistoun.
Addie, John, 144 St. Vincent street.
Alexander, Jas., Jun., 153 St. Vincent street.
Alexander, Thomas, 8 Sardinia terrace.
Allan, Thomas, Springbank.
Anderson, Alexander, 114 Trongate.
Anderson, George, M.P., Western Club.
Anderson, John, 48 Dundas street.
Anderson, Thomas, M.D., F.R.S., late Professor of Chemistry in the University of Glasgow.
Anderson, John, Bank of Scotland, Glasgow.
Anderson, T. M'Call, M.D., Professor of Clinical Medicine in the University of Glasgow, 14 Woodside crescent.
Armstrong, James, 16 Albert drive, Crosshill.
Armstrong, Wm. J., 8 Royal Exchange court.
Arnot, James Craig, 121 Douglas street.
Arrol, Archibald, 16 Dixon street.
Arrol, Walter, 16 Dixon street.
Arrol, William A., 16 Dixon street.
Arthur, Allan, Alfred terrace, Gt. Western rd.
Arthur, Wm. R., 1 Crown gardens, Dowanhill.
Aspin, James, 1 India street, West.
Auchterlonie, T. B., Bellfield, Kirkintilloch.

Bain, James, 3 Park terrace.
Bain, Robert, 22 Dundas street.
Baird, Alex. Smith, 19 Sardinia ter., Hillhead.
Baird, James, 54 St. Vincent street.
Baldie, Robert, I.A., 83 Bath street.
Balloch, Robert, 88 Union street.
Bankier, W. D., 31 St. Vincent place.
Bannatyne, Mark, 151 West George street.
Barclay, James, 224 West George street.
Barr, Thomas M., C.E., 21 Rose st., Garnethill.
Baxter, John W., Linnside, Dunoon.
Baxter, William, 14 Gibson street, Hillhead.
Beckett, John, 16 St. Vincent place.
Bell, Dugald, 27 Lansdowne crescent.
Bell, George, I.A., 37 West Nile street.
Bell, James, 41 Mitchell street.
Bell, Robert, M.D., F.F.P.S.G. and Ed., 50 Woodlands road.
Bird, Gregory, 8 Berkeley terrace.
Bischof, Gustav, Professor of Technical Chemistry, Andersonian University.
Black, Albert, 16 Park terrace.
Black, John, 16 Park terrace.
Black, D. Campbell, M.D., M.R.C.S.E., 25 Sandyford place.
Blackie, Robert, 17 Stanhope street.
Blackie, W. G., Ph.D., F.R.G.S., 17 Stanhope street.
Blair, George M'Lellan, 3 Woodlands terrace.
Blair, J. M'Lellan, 8 Cecil place, Paisley road.
Boucher, James, I.A., 177 St. Vincent street.
Bowie, Andrew, 5 India street.
Bowie, Campbell T., 26 Bothwell street.
Boyd, John, Shettleston Iron Works, near Glasgow.
Boyd, Wm., Blythswood Foundry, 61 North st.
Brodie, John Ewan, M.D., C.M., 99 Douglas st.
Bromhead, Horatio K., A.R.I.B.A., 194 St. Vincent street.
Broom, William, 182 Hope street.
Brown, Alfred, 16 St. Vincent place.
Brown, Nicol, 136 West George street.
Brown, Richard, Eglinton Chemical Company, 31 St. Vincent street.
Brownlee, James, 30 Burnbank gardens.
Brownlee, Thomas, 34 Hill street, Garnethill.
Bruce, John Inglis, 88 Hope street.
Bruce, John L., 137 West Regent street.
Bryce, James, M.A., LL.D., F.G.S., High School.
Bryce, David, 129 Buchanan street.
Bryden, Robert A., 37 West Nile street.

Buchanan, George S., 95 Candleriggs.
Buchanan, Robert M., 11 Park Grove terrace.
Buchanan, Wm. L., 14 Lynedoch crescent.
Burnet, John, 150 St. Vincent street.
Burns, James Cleland, Ochtertyre, Crieff.
Burns, John, M.D., 241 St. Vincent street.
Byers, A. Stewart, 6 South Wellington street.

Cameron, Chas., M.D., LL.D., M.P., 261 West George street.
Cameron, Robert, 61 Parliamentary road.
Cameron, Hector C., M.D., 294 Bath street.
Campbell, Colin, 2 Buckingham terrace.
Campbell, James A., LL.D., 29 Ingram street.
Campbell, John D., 5 Derby ter., Sandyford.
Cannan, John, 248 Buchanan street.
Carlile, Thomas, 23 West Nile street.
Carlton, Charles, 167 West Regent street.
Carmichael, Neil, M.D., C.M., 81 S. Portland street.
Carrick, James, Royal Hotel, George square.
Carrick, John, City Architect, 4 S. Albion pl.
Cassels, Robert, 166 St. Vincent street.
Chalmers, John, 251 Renfrew street.
Chapman, Thomas, 56 Buchanan street.
Charteris, Matthew, M.D., 184 West Regent street.
Christie, Alexander, 28 Buchan st., Gorbals.
Christie, John, Turkey-red Works, Alexandria, Dumbartonshire.
Church, James, 88 Renfield street.
Church, William, jun., 67 St. Vincent street.
Clark, John, Ph.D., 42 Bath street.
Clarke, William, I.A., 37 West Nile street.
Clark, John, 9 Wilton crescent.
Clavering, Thomas, 21 St. Vincent place.
Clinkskill, James, 176 West Regent street.
Clouston, Peter, 17 Exchange square.
Coats, Joseph, M.D., 33 Elmbank street.
Cochrane, Michael, M.A., Overdale, Langside.
Coghill, William C., 263 Argyle street.
Coleman, J. J., F.C.S., 69 St. George's place.
Collier, Wm. F., LL.D., 12 Belmont crescent.
Collins, William, 3 Park terrace, East.
Colquhoun, Hugh, M.D., Anchorage, Bothwell.
Connal, Michael, Virginia buildings.
Connell, James, 182 Crookston street.
Connell, William, 38 St. Enoch square.
Connel, Robert, M.D., 21 Corunna street.
Copeland, James, 2 Portman place, Smith st., Hillhead.
Corbet, Robert, 70 Fordneuk street.
Coubrough, A. Sykes, Blanefield, Strathblane.
Couper, James, 15 Blythswood square.
Couper, William, 141 St. Vincent street.
Cowan, John B., M.D., Professor of Materia Medica in the University of Glasgow, 159 Bath street.
Cowan, John, 8 Scotia street.
Craig, John, 24 Hamilton Park terrace.
Crawford, David, Jun., Barrowfield Printworks, Bridgeton.
Crawford, William C., M.A., Eagle Foundry.
Crawford, W. B., 104 West Regent street.
Cree, Thomas S., 17 Exchange square.
Cross, David, 51 Argyle street.
Cumming, J. Simpson, M.D., 467 St. Vincent street.

Cunliff, Richard S., 20 Renfield street.
Currie, R. J., 188 West Regent street.
Cuthbertson, John N., 29 Bath street.

Darling, George E., 247 West George street.
Davidson, Thos., Jun., 33 and 41 Garngad hill.
Day, St. John Vincent, C.E., F.R.S.E., 166 Buchanan street, *Librarian.*
Deas, Jas., C.E., 7 Crown gardens, Dowanhill.
Dick, A. Buchanan, 79 Hill street, Garnethill.
Dickson, James, 34 Kent street.
Dickson, Gavin Irving, 37 West George street.
Dixon, Edward M., B.Sc., 11 Hopetoun place.
Dixon, Joseph Anthony, 156 West George st.
Dixon, Peter W., 19 Elmbank crescent.
Dixon, Andrew Dow, 19 Elmbank crescent.
Doddrell, George John, 35 Virginia street.
Donald, John, Pollokshields.
Donald, John, St. Rollox Schools.
Donaldson, Alexander, 108 St. Vincent street.
Donaldson, James, M.D., Deputy Inspector-General of Hospitals, 6 Granby terrace, Hillhead.
Douglas, Campbell, I.A., 266 St. Vincent st.
Douie Robert, 145 Ingram street.
Downie, John, 7 Royal Bank place.
Downie, James, 69 Ingram street.
Downie, Robert, Jun., Carntyne Dyeworks, Parkhead.
Drew, Alexander, 31 Hamilton drive.
Dron, William, Cranstonhill.
Dryburgh, James N., 93 North Frederick st.
Duncan, William, Coltness Iron Co., 124 St. Vincent street.
Duncan, Ebenezer, M.D., C.M., F.F.P.S.G., 3 Brougham terrace, Crosshill.
Dunlop, Nathaniel, 8 Albany place.
Dunn, James, 34 Burnbank gardens.

Ellison, W. T., 23 St. Enoch square.
Evans, Mortimer, C.E., F.G.S., 97 W. Regent street.

Farquhar, John, Tower Bank, Lenzie.
Fergus, Andrew, M.D., M.R.C.S., England, 41 Elmbank street.
Ferguson, John, M.A., University Chemical Laboratory.
Ferguson, Peter, 2 Rochester place, Sauchiehall street.
Fergusson, Alexander A., 38 M'Alpine street.
Fergusson, Alexander, 31 Elmbank crescent.
Findlay, Joseph, 25 Lynedoch street.
Finlay, John, 18 Renfield street.
Finlayson, James, M.D., 351 Bath street.
Fisher, Donald, 194 West George street.
Fleming, J. G., M.D., 155 Bath street.
Fleming, James, Jun., Newlandsfield, Pollokshaws.
Forbes, Peter, Larbert Cottage, Larbert.
Forbes, George, B.A., F.R.S.E., Professor of Natural Philosophy in the Andersonian University.
Forrester, James M., 107 St. Vincent street.
Foulis, William, 42 Virginia street.
Frame, Thomas, Royal Bank place.
Fraser, Daniel, 113 Buchanan street.
Frew, Robert, M.E., 160 Hope street.

Fulton, David, Engraving Works, Duke street.

Gairdner, W. T., M.D., Professor of Practice of Physic in the University of Glasgow, 225 St. Vincent street.
Galbraith, Andrew, 123 Hope street.
Galbraith, William, 3 Blythswood square.
Gale, Jas. M., C.E., Water Office, 23 Miller st.
Galloway, William, H.M. Inspector of Mines, 377 Sauchiehall street.
Gardner, Daniel, 36 Jamaica street.
Gardner, O. T. B., 69 St. George's place.
Gardner, George, 68 St. Vincent street.
Garroway, Robert, 58 Buchanan street.
Geddes, William, Cathcart.
Gentles, William, 254 Sauchiehall street.
Gillies, William, Battlefield, Langside.
Gillies, T. W. D., Princes square.
Gilmour, J. B., 48 North Hanover street.
Goldie, Alexander, 78 Rutherglen loan.
Gorman, William, 13 Renfrew street.
Gossman, Adam, 23 Carlton place.
Gourlay, Robert, 10 Howard street.
Gourlay, Robert, Bank of Scotland.
Gow, Alex., Ladbroke, Grove road, Notting-hill, London, W.
Gow, Robert, Cairndowan, Dowanhill gardens.
Grant, Robert, M.A., LL.D., F.R.S., Professor of Astronomy in the University of Glasgow, *President.*
Gray, Charles, 156 West George street.
Gray, James, M.D., 15 Newton terrace.
Gray, Robert, Bank of Scotland, Edinburgh.
Gray, J. St. Clair, M.D., C.M., F.F.P.S.G., 2 Belmont terrace, Hillhead.
Greenlees, Alex., M.D., 405 St. Vincent street.
Greenlees, Wm., M.D., 11 Elmbank street.
Greenshields, James, 33 Virginia street.
Gregory, T. Currie, C.E., F.G.S., 62 St. Vincent street.
Grieve, John, M.D., 21 Lynedoch street.
Grieve, Robert, L.R.C.S., Ed., 52 Holmhead st.
Guthrie, David, C.E., 23 Miller street.
Guthrie, William, 23 Miller street.

Hallows, Frederic J., 133 West George street.
Hamilton, Andrew, Thornliebank.
Hamilton, George, 22 Renfield street.
Hamilton, J. Struthers, Adelphi Cotton Works.
Hamilton, Patrick, 22 Renfield street.
Hannah, Robert S., 80 Buchanan street.
Hannay, Anthony, 23 Exchange square.
Hannay, Robert, Blochairn Iron Co., 43 West Regent street.
Hannay, Thomas, Blochairn Iron Co., 43 West Regent street.
Harvey, Alex., Sen., 4 S. Wellington place.
Harvey, George, 9 Park quadrant.
Harvey, J. E., 2 Bath street.
Hay, John, 110 Bothwell street.
Henderson, Thomas, 47 Union street.
Henderson, William, 88 New wynd.
Henderson, William, 97 Buchanan street.
Henderson, William, 26 Renfield street.
Herbertson, Henry, 154 St. Vincent street.
Herriot, Arthur, 22 Wilson street.
Herschel, Alexander S., B.A., F.R.A.S., Professor of Physics, Durham University, 16 Saville Row, Newcastle-on-Tyne.
Heys, Zechariah J., South Arthurlie, Barrhead.
Higginbotham, James S., 147 St. Vincent st.
Hildesheim, John, 21 St. James street.
Hoey, David George, 54 St. Vincent street.
Hogg, Robert, 26A Renfield street.
Holms, William, M.P., 9 Park circus.
Honeyman, John, I.A., 61 West Regent street.
Hopkins, John, 78 Gordon street.
Houston, Campbell, Renfrew Villa, Pollokshields.
Howatt, James, 146 Buchanan street.
Howatt, William, 146 Buchanan street.
Hunt, Edmund, 87 St. Vincent street.
Hunter, Andrew, 10 Woodside place.
Hunter, Jas., Newmains House, Motherwell.
Hunter, James, 19 Union street.
Hutchison, Robert, 8 Great Western terrace.
Hutton, W. R., 77 Renfield street.

Inglis, Anthony, 64 Warroch street.
Inglis, John, 64 Warroch street.
Irvine, A. K., M.D., 3 Newton terrace.

Jack, John E., 4 Florentine terrace, Hillhead.
Jackson, John Hunter, 235 Bath street.
Jackson, Thomas, Coates House, Coatbridge.
Jacoby, Gustav, Prospect Villa, Montgomery terrace, Mount Florida.
Jaffrey, George W., The Firs, Partick.
Jamieson, John L. K., 12 Centre street.
Jeffray, John, 193 St. Vincent street.
Johnson, Rev. J.S., D.D., Manse, Cambuslang.
Johnstone, Jas., Coatbridge st., Port-Dundas.
Johnston, John, 52 West Howard street.
Johnston, William, 21 Virginia street.
Jones, William, 286 Bath crescent.

Keay, Thomas, 134 West George street.
Keddie, Wm., F.R.S.E., 5 India st., *Secretary.*
Kelley, Andrew, 82 Argyle street.
Kennedy, Thomas, Jun., 8 N. Exchange court.
Kennedy, Walter Stewart, Allanbank, Crosshill.
Kerr, James Henry, 20 Dunlop street.
King, Jas., 6 Windsor terrace, St. George's rd.
King, James, Hurlet and Campsie Alum Co., 204 West George street.
King, John, 13 Renfield street.
Kirk, Alex. C., Govan park, Govan road.
Kirkpatrick, Andrew J., 24 Berkeley terrace.
Kirkwood, Dr. Anderson, 12 Windsor ter., W.
Kirsop, John, 98 Argyle street.
Knox, Andrew L., 12 India street.
Knox, John, 70 St. Vincent street.

Laing, Alexander, LL.D., Professor of Mathematics in the Andersonian University.
Laird, George, 10 Ann street, Bridgeton.
Lamb, James, 50 Wilson street.
Lamb, Thomas, 190 Parliamentary road.
Lang, J. L., 30 Cochran street.
Lang, William, Jun., 190 West George street.
Laughlen, Andrew, C.E., 58 St. Vincent street.
Leggat, Robert, 29 Maxwell street.
Leisler, Louis, 146 West George street.
Lindsay, William G., 8 West Regent street.
Lindsay, Archd. M., M.A., 87 West Regent st.
Lindsay, Rev. Thomas M., D.D., M.A., F.R.S E., F.A.S., Professor in the Free Church College.

Lockhart, Robert, 234 St. George's road.
Long, John Jex, 12 Whitevale.
Lothian, John Alexander, M.D., L.R.C.S.E., 87 Sauchiehall street.
Lumsden, Sir James, 20 Queen street.

M'Adam, William, 45 Hydepark street.
M'Alley, Robert, Chemical Works, Falkirk.
M'Andrew, John, 17 Park street, East.
M'Arthur, Alexander, 82 Glassford street.
M'Arthur, D., 26 Bothwell street.
Macarthur, J. G., 116 St Vincent street
MacBean, Hugh, 24 Woodside place.
M'Call, James, V.S., Professor of Veterinary Medicine and Surgery, Veterinary College, 395 Parliamentary road.
M'Callum, George, Rossbank, Cambuslang.
M'Conville, John, M.D., 27 Elmbank place.
M'Cowan, Robert, C.A., 87 St. Vincent street.
M'Creath, James, M.E., 138 West George st.
M'Culloch, Richard, 93 West Regent street.
M'Culloch, William, 134 Bath street.
Macdonald, Archibald G., 8 Park circus.
M'Donald, John, Comely Park House.
Macdonald, Thomas, 203 Hope street.
M'Ewan, Malcolm, 23 St. Enoch square.
M'Ewen, William, Jun., 11 Park terrace.
Macfarlane, Walter, Saracen Foundry, Possil park.
M'Farlane, Walter, Printworks, Thornliebank.
M'Farlane, Robert, 28 Napiershall street.
M'Gavin, John, 19 Elmbank place.
MacGill, J. S., 2 Clifton street.
M'Goun, David J., 7 Berkeley terrace.
M'Gregor, Duncan, F.R.G.S., 45 Clyde place.
M'Gregor, James W., 4 Great Western terrace, Hillhead.
M'Gregor, David, Manager, Allander Printworks, Milngavie.
M'Gregor, James, 2 Queen's terrace.
M'Grigor, Alexander B., 186 St. Vincent street.
M'Ilwraith, James, 6 Berkeley terrace.
M'Intosh, James, 129 Stockwell street.
M'Intyre, Peter, 122 Brunswick street.
Mackay, John, Jun., 270 Sauchiehall street.
Mackenzie, Alexander, 89 Buchanan street.
M'Kendrick, John, 25 Berkeley terrace.
Mackinlay, David, 6 Great Western terrace, Hillhead.
M'Laren, Robert, Canal street, Port-Eglinton.
M'Laren, William Edward, 80 Renfield street.
Maclean, A. H., 124 Queen street.
Maclean, Thomas, 124 Queen street.
Maclean, William, Jun., 98 West George street.
Maclehose, James, 18 Victoria cres., Dowanhill.
Macleish, J. M., 10 Hamilton drive, Hillhead.
Maclellan, Allan H., 6 Lansdowne crescent.
M'Lellan, Lewis, 26 India street.
M'Lellan, Walter, 129 Trongate.
Macleod, Kenneth M., 1 Montrose street.
Macnab, Robert, 135 Buchanan street.
Macnee, Daniel, R.S.A., 178 Bath street.
M'Nicol, Peter, M.A., 186 North street.
M'Onie, Andrew, Scotland street, Tradeston.
M'Pherson, James, M.D., 115 Bath street.
M'Pherson, George L., 37 M'Aslin street.
Mactear, James, F.C.S., St. Rollox Chemical Works.
M'Vail, D. C., 96 New City road.
Main, James, A.R., 9 Renfield street.
Malloch, Charles, 12 Croy place.
Mann, John, C.A., 83 W. Regent st., *Treasurer.*
Mann, Thomas, 204 West Regent street.
Marshall, James, 8 Somerset place.
Martin, John M., 142 St. Vincent street.
Martin, Thomas, 122 Sauchiehall street.
Martin, Thos., 19 Rupert st., Great Western rd.
Mason, Stephen, 47 Queen street.
Masterton, Robert Knox, 38 Elmbank crescent.
Mathieson, John A., 203 Hope street.
Mathieson, Thomas A., 13 East Campbell st.
Mayer, John, F.C.S., 2 Carlton place.
Mayer, E. L., 209 Hope street.
Mein, Alexander, 12 Buckingham terrace.
Meldrum, Edward, of Dechmont, Broxburn.
Melvin, William, 89 South Portland street.
Menzies, Thomas, Hutchesons' Hospital School, Crown street.
Middleton, Robert T., 57 West Nile street.
Millar, David, 6 Royal terrace.
Millar, James, 124 Parliamentary road.
Millar, William, 2 Albany pl., Sauchiehall st.
Millen, Ebenezer, M.A., 90 Buccleuch street.
Miller, Alexander, Jun. (Messrs. Inglis & Wakefield), 74 Gordon street.
Miller, Daniel, C.E., 203 St. Vincent street.
Miller, Hugh, M.D., F.F.P.S., 8 Crescent pl.
Miller, James, Port-Dundas Pottery.
Miller, James, 21 Woodside place.
Miller, John S., 54 Gordon street.
Miller, John (Messrs. James Black & Co.), 23 Royal Exchange square.
Miller, Thomas P., Cambuslang Dye Works.
Miller, W. M., 5 Shaftesbury terrace, West Regent street.
Miller, William, 147 St. Vincent street.
Miller, William, 7 Victoria terrace, Dowanhill.
Mirrlees, James B., 45 Scotland st., Tradeston.
Mitchell, Alexander, Jun., 10 Wilton crescent.
Mitchell, Angus, 42 Miller street.
Mitchell, Robert, 8 Florence pl., Woodlands rd.
Moffatt, Alexander, 47 Union street.
Moir, Alexander, 73 Mitchell street.
Moir, P. M., 51 Crawford street, Port-Eglinton.
Moore, Alexander, C.A., 166 St. Vincent st.
Moore, William, M.E., 49 West George street.
Morgan, John, Springfield House, Bishopbriggs.
Morrice, Alexander, 27 Abbotsford place.
Morrison, George, 19 Royal terrace.
Morrison, James, 52 Sauchiehall street.
Morton, Alexander, 62 Buchanan street.
Morton, James, M.D., Professor of Materia Medica in the Andersonian University, 199 Bath street.
Mossman, John, 83 North Frederick street.
Muir, Matthew, 17 Carlton place.
Muir, Matthew A., 20 Park terrace.
Muir, M. M. Pattison, F.C.S., 12 Woodlands terrace.
Muir, Thomas, 17 Carlton place.
Muirhead, Andrew Erskine, Cart Forge, Crossmyloof.
Muirhead, Henry, M.D., Bushy Hill, Cambuslang.
Muirhead, Thomas, 5 Allanton ter., Crosshill.
Munro, Daniel, 7 Park quadrant.

Munsie, George, 845 Bath street.
Murdoch, James B., Hamilton place, Langside.
Murdoch, James, 137 Bath street.
Murray, John Bruce, 97 Mitchell street.
Murray, George, 97 Mitchell street.

Nairn, Archibald, 24 Cochran street.
Napier, Jas., F.C.S., Cuprum House, Partick.
Napier, James, Jun., 21 Roselea drive.
Napier, James R., F.R.S., 22 Blythswood square.
Napier, John, Saughfield House, Hillhead.
Neil, John, Whitehill House, Dennistoun.
Neilson, Walter, 172 West George street.
Neilson, Walter M., Hydepark Works, Springburn.
Neilson, William, 48 Renfield street.
Nicol, David, 18 Nelson terrace, Hillhead.
Nicol, James, City Chambers.
Nicolson, Thomas, 156 St. Vincent street.

Ormond, J. M., M.A., The Park School.
Osborne, Alex., 5 Oakley terrace, Dennistoun.

Paris, Wm., Glasgow Iron Works, St. Rollox.
Paris, William, Jun., Glasgow Iron Works.
Paterson, Adam, LL.D., 45 West George st.
Patterson, T. L., 29 Cathcart street, Greenock.
Peden, William N., 8 Hilton terrace, Crosshill.
Pennycook, C. H., 100 Montrose street.
Poynter, John E., 8 Princes square, Buchanan street.
Pringle, Quintin, B.Sc., LL.B., 6 Hamilton place, Great Western road.
Provan, James, 17 Gordon street.

Ramsay, John, of Kildalton, M.P., 140 Bath st.
Ramsay, William, C.E., 49 West George street.
Randolph, Charles, 4 Park terrace.
Rankine, Capt. John, 257 St. Vincent street.
Rankine, John, Turkey-red Dye Works, Strathclyde.
Raphael, Robert, 146 West George street.
Readman, Robert, 6 Sandyford place.
Reid, Douglas, Easterton, Helensburgh.
Reid, James, Wellfield House, Springburn.
Reid, James, Dunmullin House, Strathblane.
Reid, Thomas, M.D., 9 Elmbank street.
Renison, William, 20 Buchanan street.
Renshaw, C. Buie, Glenpatrick, by Paisley.
Richardson, George, 115 St. Vincent street.
Ritchie, William, Jun., Kincaidfield House, Milton of Campsie.
Roberton, James, LL.D., Professor of Conveyancing in the University of Glasgow, 13 Newton place.
Robertson, Andrew Carrick, 116 St. Vincent st.
Robertson, Archibald, 25 Queen street.
Robertson, David, F.G.S., 108 Woodlands road.
Robertson, David, 90 St. Vincent street.
Robertson, James, 1 Clifford street, Paisley rd.
Robertson, John, Newhall Factory, Greenhead.
Robertson, John, 83 Cumberland street, West.
Robertson, R. Blair, 5 Bloomfield pl., Hillhead.
Robertson, Thomas, 122 Wellington street.
Robertson, William, C.E., 123 St. Vincent st.
Robson, Robert, 12 Dixon street.
Rottenburg, Paul, 146 West George street.
Rowan, David, 22 Woodside place.
Rowan, W. H., Clydeford, Rutherglen.
Russell, James B., B.A., M.D., 278 Bath st.
Russell, Thomas, 14 India street.

Salmon, James, I.A., 197 St. Vincent street.
Salmon, Wm. Forrest, I.A., 197 St. Vincent st.
Sandeman, David, Woodlands, Lenzie.
Schuman, Sigismund, 7 Royal Bank place.
Scott, Alexander, 19 St. Vincent crescent.
Scott, James, 99 Breadalbane ter., Garnethill.
Scott, E. J., 24 Sardinia terrace.
Scott, Thomas, 1 North Ure place.
Seligmann, Hermann L., 49 West George st.
Selkirk, James L., 136 Buchanan street.
Sellars, James, Jun., 266 St. Vincent street.
Sim, William, 88 Great Clyde street.
Sinclair, Neil, 42 Miller street.
Slessor, John, 92 Abbotsford place.
Small, Thomas, 4 Lynedoch place.
Smart, Robert, M.D., 22 St. George's road.
Smellie, Thomas D., 209 St. Vincent street.
Smith, A. Wood, M.D., F.F.P.S.G., 5 Newton terrace.
Smith, Geo., Sun Foundry, Parliamentary rd.
Smith, J. P., C.E., Greenside villa, Copeland road, Govan.
Smith, James, Benvue, Dowanhill.
Smith, James, 21 Bath street.
Smith, Hugh C., 54 Gordon street.
Smith, Napier, 68 St. Vincent street.
Smith, Robert, 124 Sauchiehall street.
Smith, William, 20 Ropework lane.
Smith, W. R. W., 6 South Hanover street.
Smith, William A., 5 South Hanover street.
Smith, James Graham, 18 Park Circus place, Park street, East.
Stanford, Edward C. C., F.C.S., Carruth, Bridge of Weir.
Steel, James, 25 Holmhead street.
Stephen, Robert R., Adelphi Biscuit Factory.
Steven, Alexander, Jun., 6 South Park terrace, Hillhead.
Steven, Hugh, 4 Buckingham terrace.
Steven, William, 481 London road.
Stevenson, James, Jun., 23 West Nile street.
Stevenson, John, 28 West Nile street.
Stevenson, Robert, 2 West Regent street.
Stevenson, William, 4 Berkeley terrace.
Stewart, David, 128 Ingram street.
Stewart, David Y., 3 Provan place, North Montrose street.
Stewart, James R., 30 Oswald street.
Stewart, John, 8 Montague place, Bath street.
Stewart, Peter, M.D., 1 Albany place.
Stewart, William, 99 St. Vincent street.
Stillie, Thomas L., 157 Buchanan street.
Stoddart, James Edward, Dalquhurn Dye Works, Renton.
Storer, David, Colour Works, Sydney street.
Strathern, John, Turkey-red Dye Works, Blantyre.
Stronach, Alexander, City of Glasgow Bank.
Sutherland, Robert, 18 Berkeley terrace.
Swan, William, Collina Cottage, Maryhill.
Swanston, John, 1 Grafton square.
Symington, Andrew, 119 St. Vincent street.

Tatlock, Robt. R., F.R.S.E., F.C.S., 42 Bath st.

Taylor, John, Jun., 28 Cochran street.
Taylor, Benjamin, 7 Walworth terrace.
Teacher, Adam, 17B St. Enoch square.
Teacher, Donald M., 20 Park circus.
Teacher, William, 17B St. Enoch Square.
Tennant, Charles, St. Rollox Chemical Works.
Tennant, John, 115 St. Vincent street.
Thomson, Alexander, 122 Wellington street.
Thomson, Allen, M.D., F.R.S., Professor of Anatomy in the University of Glasgow, *Vice-President.*
Thomson, David, I.A., 29 St. Vincent place.
Thomson, George, 69 Ingram street.
Thomson, George P., 2 Newton place.
Thomson, Graham Hardie, 1 Scotland street, Woodlands road.
Thomson, James, F.G.S., 276 Eglinton street.
Thomson, James (Messrs. Allan & Mann), 48 St. Enoch square.
Thomson, James, I.A., 61 West Regent street.
Thomson, James R., Clydebank Foundry.
Thomson, James, LL.D., C.E., Professor of Engineering in the University of Glasgow.
Thomson, John D., 4 Rosslyn terrace, Victoria park.
Thomson, John Millar, University.
Thomson, Jonathan, 136 West George street.
Thomson, Sir William, LL.D., F.R.S., Professor of Natural Philosophy in the University of Glasgow.
Thomson, William, 80 Buchanan street.
Thorpe, T. E., Ph.D., F.R.S.E., Professor of Chemistry in the Andersonian University.
Townsend, Joseph, 18 Crawford street, Port-Dundas.
Townsend, Robert, 128 Bishop street, Port-Dundas.
Turnbull, Andw. H., Dunard Villa, Dowanhill.
Turnbull, John, 37 West George street.
Turnbull, John Joseph, 37 West George street.

Ure, John, Crown Mills, 68 Washington street.

Virtue, John, 57 St. Vincent crescent.

Walker, Archibald, 4 Muirhead street.
Walker, James, Jun., 175 West George street.
Walker, John, Dalmarnock Dye Works.
Walker, Malcolm M'N., F.R.A.S., 45 Clyde pl.
Walker, William, 1 West Regent street.
Wallace, William, Ph.D., F.R.S.E., F.C.S., 42 Bath street.
Watson, Eben., A.M., M.D., Professor of Institutes of Medicine in the Andersonian University, 1 Woodside terrace.
Watson, George, Phœnix Office, 68 St. Vincent street.
Watson, James, 2 Florentine place, Hillhead.
Watson, Thomas, 68 St. Vincent street.
Watson, Thomas Wilkinson, 8 Grafton place.
Watson, William West, F.S.S., City Chamberlain, Council Chambers.
Watson, William Renny, 16 Woodlands terrace.
Watson, Robert, 42 Hutcheson street.
Watt, Alexander, 67 Renfield street.
Wenley, James A., 8 Lynedoch place.
Westlands, Robert, 8 Howard street.
Whitelaw, Alexander, 87 Sydney street.
Wilson, Daniel, 124 Renfield street.
Wilson, David, 145 Ingram street.
Wilson, J. G., M.D., F.R.S.E., F.R.C.S.E., Professor of Midwifery in the Andersonian University, 9 Woodside crescent.
Wilson, J., 468 Gallowgate.
Wilson, J. Veitch, 116 St. Vincent street.
Wilson, John, 11 Woodside place.
Wilson, Wm., Holmhurst, Dowanhill gardens.
Wingate, Paterson, Broomhall, Partick.
Wingate, William, Jun., 12 Garthland street.
Wolfe, J. R., M.D., F.R.C.S.E., 18 Brandon place.
Wood, John Muir, 42 Buchanan street.
Woodburn, J. Cowan, M.D., 187 Sauchiehall st.
Wright, Strethall H., M.D., C.M., M.R.C.P.E., Barony Hospital and Asylum, Barnhill.
Wright, Thomas, 128 Bothwell street.
Wulff, Seigmund, Dunallan, Partick Hill.
Wünsch, Edward A., 146 West George street.

Young, James, F.R.S., Kelly, Wemyss Bay.
Young, John, M.D., F.R.S.E., Professor of Natural History in the University of Glasgow, 18 Hillhead gardens, *Vice-President.*
Young, John, Jun., Forth street, Port-Dundas.
Young, Robert, Castlehill, Pollokshields.
Young, William, Forth street, Port-Dundas.
Younger, George, 1 North Exchange Court.
Yule, John, 28 Carlton place.

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

SEVENTY-SECOND SESSION.

XI.—*On the Family Cyathophyllidæ—Tribe, Aspidiophyllacea—Genus, Aspidiophyllum.* By James Thomson, F.G.S.

[Read before the Society, 4th Nov., 1874.]

The object of this communication is to describe a new genus of Rugose corals from the mountain limestone of Scotland, which I discovered many years ago in Thirdpart Quarry near Beith, Ayrshire. For a number of years I had grave doubts as to the true classification of this group, as several of the specimens, previous to their being sectioned, might readily be mistaken for, and classified amongst Dana's genus *Clisiophyllum.* I have frequently seen it named as *Clisiophyllum coniseptum.* Indeed there is a perfect agreement in the general resemblance of the external aspect of some of the species; but a considerable difference in structural details is observed after the specimens have been sectioned and compared. In a longitudinal section the centre of the coral in both cases is filled up with endothecal dissepiments that laterally unite the lamellæ. But the arrangement of each differs widely. In Clisiophyllum they are convex—convexity upwards and outwards—and are arranged around the columellarian line that is seen passing down the centre of the genus, and which terminates in the centre of the calice in the form of a conical boss, or like a small tent; whereas in the new genus *Aspidiophyllum* the boss in the centre of the calice differs, not only in its external aspect, being outlined like a helmet, round on the superior extremity on the concave side, and tapering down to the fossula, which is situated on the

convex or dorsal side of the coral; but also in the arrangement of the dissepiments, which laterally unite the lamellæ that spring from the inner margin of the primary septa, and ascend the columellarian protuberance in the centre of the calice. The median lamella passes for two-thirds of the length of the helmet-shaped boss, and passes downwards and tapering into the fossula as a prominent ridge. The spaces between the lamellæ are always wider apart on the dorsal side than the ventral, see Pt. I., fig. 2; and the dissepiments that laterally unite the lamellæ are always concave, see Pt. I., fig. 1. In all instances there is no difficulty in determining the latter where the calice is well preserved, the columellarian base in the centre of the calice being helmet-shaped and differing so widely in outline from Clisiophyllum, its nearest ally—in the latter the boss being always shaped like a small tent. If, however, the perfect calice be awanting, if there is either a transverse or a longitudinal section of the coral for comparison with the accompanying plates, the observer will at all times be enabled to identify either genera or species.

Family, . .	CYATHOPHYLLIDÆ.
Tribe, . .	ASPIDIOPHYLLACEA.
Genus, . .	ASPIDIOPHYLLUM.

Generic characters—Corallum cylindriconical, tall, frequently found six inches in length; curved, circular accretions, ridges irregular; calice circular, shallow, and everted in some forms, whilst in other forms it is thin around the margin, and moderately deep; septa thin with well marked lamina for about half their length from the inner margin, where they become flexous; columellarian boss prominent and helmet-shaped, one-half dome-shaped, whilst the other half slopes down to the inner margin of the primary septa, on the dorsal side of the calice. See Pt. I, fig. 7. Lamellæ in the form of keeled ridges, the median lamella longer than the others, and passing over the boss, and descending in the form of a prominent keel, and passing into the fossula, on the anterior side of the calice. A vertical section shews (see Pt. I., fig. 1.) that the central area is distinct from the genus Clisiophyllum, its nearest ally, the columella is essential, and formed of laminæ which arise from the base of the corallum, and is laterally united by concave endothecal dissepiments. Fossula with small septa in it, and a portion of the endotheca of the central mass passes into it.

In establishing this genus I do so for the reception of a group of corals that I discovered many years ago in Thirdpart Quarry,

three miles to the south of Beith, Ayrshire, and I have subsequently found them in several localities throughout the central valley of Scotland, and in general they are found in a band of shale that overlies the lowest post of limestone. They seem to be more or less gregarious, as whenever they are found, they are frequently found in great numbers; at Dunbar they are very numerous, but in this locality they seem to have been exposed to the abrading and crushing influences of shore deposits, the internal structure being nearly all more or less crushed and destroyed. While conducting the cutting and polishing operations, in investigating the corals from the different localities, I had eighty-seven specimens from this locality cut at one time, and only four of their number had the structure sufficiently preserved to allow of identification. In Fifeshire I have discovered them in a dark matrix; but in this locality, as in some of the others, their existence seems to have been violently cut off by a sudden influx of sedimentary impurities fatal to their growth and final extinction. I have got them in a similar horizon near Mold in Wales, and near Penrith in Cumberland, and also in Castle-espie Quarry in the County of Down, Ireland.

Aspidiophyllum Koninckiana. Thomson. *Sp. Nov.*

Part I., Figs. 1. and 1A.

Specific characters—Corallum tall, curved, and marked with broad accretion ridges, calice awanting, transverse section circular, central area seven lines broad, and nine lamellæ, which are attached to the inner margin of the primary septa by endothecal dissepiments, and pass inwards to near the centre of the columellarian space, which is composed of minute semicircular, vesicular plates. There are sixty-eight primary septa, formed by distinct laminæ and flexous towards their outer margin, with an equal number of minute flexous secondary septa, which pass inwards from the epitheca for about a line in length, there they bend and become attached to the primary septa. The interseptal spaces are filled with numerous minute angular dissepiments. Fossula has two of the primary septa shorter than the others in it.

Vertical section triareal; outer area seven lines broad on each side, and composed of minute semicircular vesicular cells, arranged in oblique rows, convexity upwards and inwards; middle area three lines broad and formed of less convex vesicular plates and passing into the central area. In the centre area there is a line visible

passing down the middle of the section, whilst other lamellar lines are seen passing interruptedly downwards, and each is laterally united by minute concave tubula.

Corallum imperfect, it being broken at both extremities. Height of specimen 4 inches, diameter 1¼-inch. Found at Thirdpart Quarry, three miles to the south of Beith, Ayrshire, in a band of shale that overlies the lowest post of limestone.

This elegant species I have dedicated to my excellent friend Professor De Koninck of Liège, Belgium, whose valuable works and suggestions have been of incalculable service in guiding and assisting me to a systematic classification of the carboniferous corals. He has, in the most generous manner, presented me with a beautiful collection of Belgium corals, which I shall ever treasure as a souvenir of the friendship of one of the most experienced palæontologists of our age.

Fig. 7 and 7A is a young specimen, calice circular and moderately deep, columellarian boss helmet-shaped, from which I take the generic name. This specimen and figs. 2 and 2A, 4 and 4A, 8 and 8A, seem to be young specimens of the above species.

Found at Brockley, five miles to the south of Lesmahagow, Lanarkshire, in a band of shale that underlies the band of limestone in which *Productus gigantea* is found, and associated with a variety of other forms of coralline remains, the most abundant of which is *Lithostrotion junceum.* In order that the transitions that occur in this genus may be as clearly defined as possible, I have delineated a number of the varieties, from the youngest stages of growth upwards; and to the perfect condition in which many of these forms are found alone can I lay any claim to being able to classify them in a different genus; and in order that there should be no doubts regarding the proper classification of these and other forms, I recently went over to the continent, and examined the types of M. Edwards and J. Haims in Paris, and Prof. De Koninck in Belgium, and compared them with the structural details as delineated in my plates; and to Prof. De Koninck I beg to express my profound thanks, as to his kindness alone am I indebted for all the facilities I enjoyed, and for any information that I have ever received upon the Rugose corals of the carboniferous period.

Aspidiophyllum Huxleyana. Thomson. *Sp. Nov.*

Part I, Fig. 3, and Part 2, Fig. 1.

Specific characters—Corallum short, cylindriconical, and marked with irregular accretion ridges; calice circular, shallow, and everted;

columellarian boss prominent, ½-inch broad, and helmet-shaped, and formed of short lamellæ, central space composed of lax cellular endothecal dissepiments; the lamellæ in the form of keeled ridges. There are sixty-six primary septa exhibiting distinct lamina and flexous towards their outer margins, with an equal number of minute flexous secondary septa, and laterally united by minute angular dissepiments. Fossula with two of the primary septa in it shorter than the others. One of the primary septa opposite the point where the arrow is marked, is much shorter than the others. In the open interseptal space there is a small tube four lines long lying in a slanting direction, around the inner margin of which there is a group of ovular bodies, resembling ova, and being in close proximity to the inner margin of the primary septa I am inclined to think they are ova. A question, however, naturally presents itself—viz., how could the ova become fossilised and retain their ovular forms? This may be accounted for by supposing that their preservation had been the result of disease in that portion of the polyp's body, previous to their being ejected; and that the diseased portion having lost its vital functions, and consequently not being ejected, the ova were necessarily imbedded, and finally enveloped in the silo-calcareous matter of which the coral is composed. The fact of their being in that form is interesting and highly suggestive and worthy of further investigation. This being the only specimen in which I have found these ovular bodies, I felt the desirability of not asserting positively that they are ova until other corroborative evidence is discovered. It is noteworthy, however, that in making a transparent section, in order to see whether they were local or otherwise, I ground away about the 500th part of an inch off the face of the specimen, and reduced their number from twenty to about half that number (see plate 2, fig. 1, which is enlarged four diameters), establishing beyond all doubt that they are sufficiently local and minute to warrant us in, at least, assuming that if not ova, they much resemble ova. In the meantime I merely wish to record the discovery, in order that the attention of other observers may be directed to this important point. The solution of the problem being important biologically, I have much pleasure in dedicating the species to the name of Prof. Huxley, one of our greatest biologists. Found in a thin band of shale that overlies the lowest post of limestone in Thirdpart Quarry, three miles to the south of Beith, Ayrshire.

Aspidiophyllum Cruciform. Thomson. *Sp. Nov.*

Part 1, Fig. 5.

Specific characters—Corallum cylindriconical, curved, short, epitheca coarsely granulated, accretion ridges irregular, calice circular and everted, columellarian boss prominent, helmet-shaped, oval in outline, and crowned by lamellæ in the form of keeled ridges; the median lamella is more prominent than the others, which in a transverse section present the form of a Maltese cross. There are fifty-two primary septa, with distinct lamina for a third of their length from the inner margin, where they become flexous and pass outwards to the epitheca, and an equal number of secondary septa, which pass for one line inwards from the epitheca. Where they bend and are united to the primary septa, the interseptal spaces are filled up by numerous angular dissepiments. Fossula with three of the primary septa shorter than the others in it. Height of corallum, 2 inches; breadth of calice, 1 inch 3 lines.

This species differs from the preceding in the elliptical aspect of the columellarian boss, and in the cruciform aspect in a transverse section.

Found in a band of shale that overlies the lowest post of limestone in Thirdpart Quarry, three miles to the south of Beith, Ayrshire.

Aspidiophyllum Elegans. Thomson. *Sp. Nov.*

Part 1, Figs. 9 and 9A.

Specific characters—Corallum cylindriconical, and presenting well marked irregular accretion ridges, calice circular, shallow, with a thin everted edge; columellarian boss prominent, helmet-shaped, with lamellæ, median lamella prominent and forming a keeled ridge, and passing down into the fossula. There are sixty-eight primary septa, each formed by lamina for a third of the distance from the inner margin, where they become flexous and pass to the epitheca. There are an equal number of secondary septa, which pass inwards from the epitheca for two lines, where they bend and are attached to the primary septa, and each is united by vesicular interseptal dissepiments. Fossula with one of the primary septa shorter than the others in it. Height of corallum unknown, there being only a portion of it 1½ inch long. The lower extremity is awanting.

Found in Thirdpart Quarry, three miles S.E. of Beith, Ayrshire, in a thin bed of shale that overlies the low post of limestone.

Aspidiophyllum Hennedii. Thomson. *Sp. Nov.*

Part 1, Fig. 6.

Specific characters—Corallum curved turbinate, and marked with thick, irregular accretion ridges; calice circular and moderately deep, with a thin everted edge; columellarian boss small and elliptical, prominent; epitheca thick and roughly granulated. Sixty-four primary septa with distinct thin lamellæ; the outer margin becomes flexous. There is an equal number of short secondary septa, one and a-half lines long, passing inwards from the epitheca, and each is laterally united by angular interseptal dissepiments. Fossula in the convex side of the corallum, with two of the primary septa shorter than the others in it. Height of corallum, 2 inches; breadth of calice, 1 inch 4 lines.

Found in the thin shale band that overlies the low post of limestone in Thirdpart Quarry, three miles S.E. of Beith, Ayrshire.

This form differs from the preceding in the general outline of the corallum, and in the elliptical aspect of the columellarian boss, also the endothecal dissepiments are more lax than others, and the remarkable growth of the inner area in that portion of the corallum that is bounded by the interseptal locula which is produced beyond the calice about a half of an inch, suggesting that the outer margin of the polyp had lost its vitality, while in the region of the interseptal locula it continued to secrete the ingredients of which the corallum is composed. I have discovered several forms belonging to this genus, and only in this locality, exhibiting similar abnormal aspects. Indeed, I have specimens in which that portion of the corallum is produced for at least five inches above the calice.

I have much pleasure in dedicating the species to my much esteemed friend Mr. Roger Hennedy, Lecturer on Botany in the Andersonian University of Glasgow, a gentleman who is ever ready to assist and give the benefit of his great acquirements to all true students of Natural History, and to whom the author is indebted for many obligations.

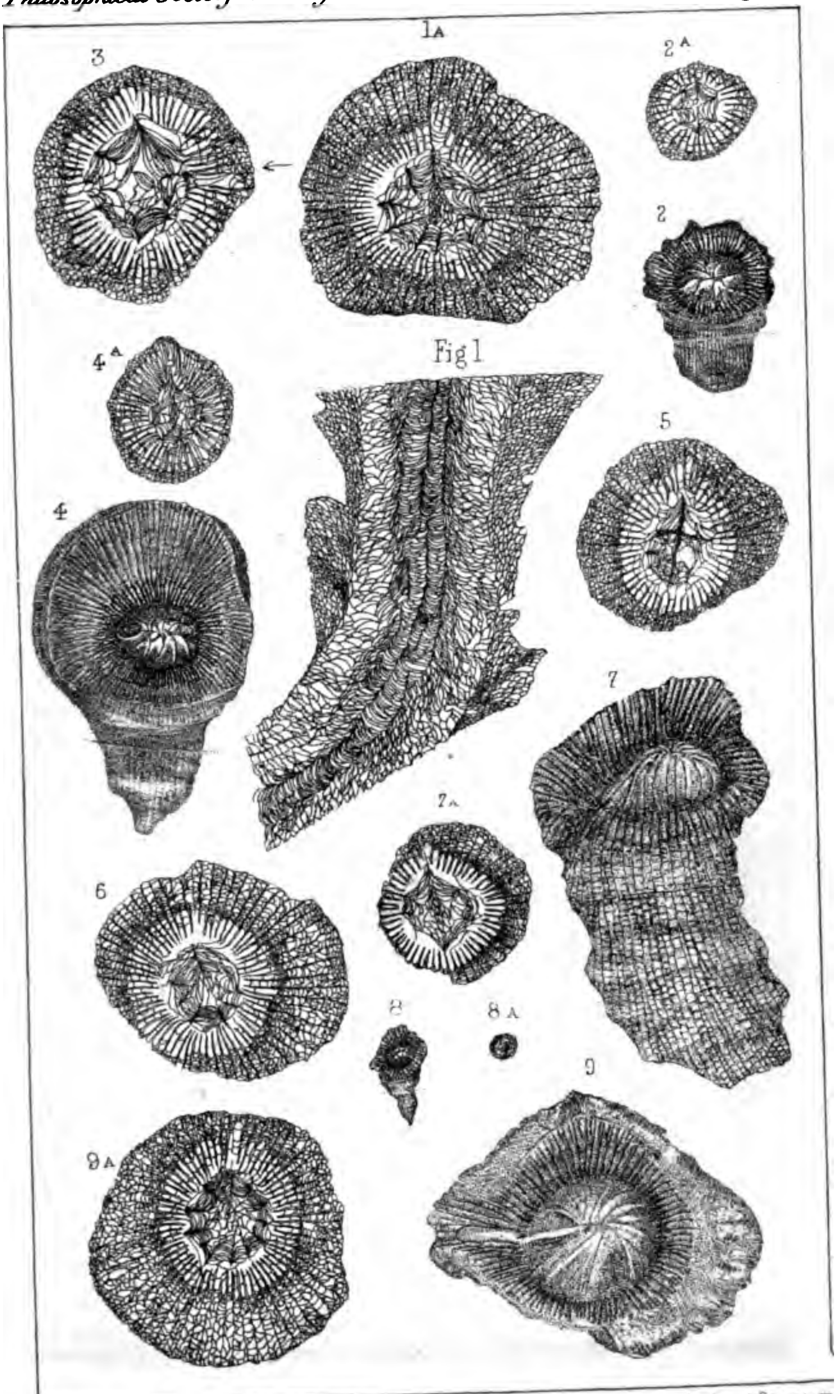
DISCUSSION ON MR. THOMSON'S PAPER.

Mr. WUNSCH bore testimony, from personal experience, to the astonishing labour Mr. Thomson must have undergone in investi-

gating these corals. The Philosophical Society was very lucky in getting such a paper, with so many beautiful illustrations, which properly belonged to the Geological Society.

Mr. MAYER suggested that Mr. John Young, although not a member of the Society, might be called on for some remarks on the paper, with the subject of which he was well acquainted.

Mr. JOHN YOUNG said—Not having made carboniferous corals my speciality, I am afraid I cannot add very much to the clear descriptions Mr. Thomson has given us, so that what I have to say will be somewhat general. It is well known throughout Britain and other parts of the world where investigations are going on in carboniferous corals, that Mr. Thomson has done a great deal in elucidating the history of many of these interesting organisms. Mr. Thomson has made a speciality of these corals, and has brought many new genera before us which, if previously known, were only imperfectly figured and described. The group of corals which Mr. Thomson has investigated are perhaps not to be equalled, as regards their state of preservation, in any other carboniferous strata on the surface of the globe. He has had the opportunity of examining specimens from many other parts, and he has stated that, without exception, those belonging to the Glasgow coal field are the best preserved he has yet met with. If he continue his investigations, I have no doubt he will still continue to meet with new forms which have not been properly determined nor described. These organisms belonged to a class of corals that closed their life, so far as known, with the Palæozoic Period, none of the group being found in the strata of the Secondary and Tertiary Periods, and none exist in our recent seas. They are found in very great abundance in certain of the strata of the carboniferous limestone series, and it is surprising with what beauty their internal structures are preserved in most cases. The parts that are left us, and which form the fossil coral, are only the hard parts secreted by the animal. The soft parts of the animal itself sat in these cups, just as one of our recent sea-anemones does on the rock to which it is attached, only with this observable difference, that our recent anemones, which belong to the same division of the animal kingdom, do not secrete a calcareous skeleton as these ancient corals did. When we see the diversity of structure between one of these corals and another, we must admit that there was a similar diversity in the soft parts of the animals themselves, so that it is only by the minute study of the various parts, obtained by cutting longitudinal and transverse



Jas. Thomson Del.

Gardner & Stevenson

CARBONIFEROUS CORALS.

To illustrate Mr Thomson's paper

sections of the coral, that we can obtain a clear knowledge of the true structure of the skeleton of the animal. The study of these old forms of coralline life is a very interesting one, and is well worthy of all the care and attention that Mr. Thomson has bestowed on it. In reference to what Mr. Thomson has said about the ova being preserved in the fossula of one of his specimens, we do not know of any recent ova of zoophytes which would be likely to be preserved in a calcareous state within the soft body of the animal. Many soft-bodied zoophytes may have existed along with these carboniferous corals, just in the same condition as the anemones of the British seas do exist, yet none of them are found to be preserved in a fossil state. This gives all the greater interest, therefore, to the forms of turbinated corals that are preserved to us. These corals, in some districts, exist in such abundance as to form ancient coral reefs of local extent, and it is an interesting fact that many of these reefs are found in the neighbourhood of volcanoes of the carboniferous period, shewing that heat to some extent was necessary for their existence over these tracts of the sea-bottom. The fossils are in many cases interstratified with beds of volcanic or trappean ash. I hope Mr. Thomson may continue his researches in this branch of study. I also wish that many more workers would make specialities of particular branches of Natural History as truly as Mr. Thomson has done.

EXPLANATION OF THE PLATES.

Plate I.

Fig. 1.—*Aspidiophyllum Koninckiana.* Thomson. Natural size. Shewing the triareal arrangement of the vesicular cells; outer area shewing arrangement of the dissepiments that fill up the interseptal spaces. Also, those of the interlocular spaces in the middle area, and the arrangement of the minute concave tabulæ that laterally unites the lamellæ in the central area.

Fig. 1A.—A transverse section of the same, shewing the form and arrangement of the septa, and the lamellæ of the columellarian space.

Fig. 2.—A young specimen belonging to the preceding species. Calice imperfect.

Fig. 2A.—A transverse section of the same, shewing the arrangement of the septa and the lamellæ in the earlier stages of growth.

Fig. 4.—Another young specimen of the same, with broad everted calice.

Fig. 4A.—A transverse section of the same.

Fig. 7.—A larger specimen of the same, shewing the helmet-shaped boss in the centre of the calice. A portion of the margin of the calice and the epitheca is eroded away by atmospheric agencies.

Fig. 7A.—A transverse section of the same.

Fig. 8.—A young specimen of the same.

Fig. 8A.—A transverse section of the same.

Fig. 2.—*Aspidiophyllum Huxleyana.* Thomson. A transverse section, shewing the form of the septa and the remarkable arrangement of the lamellæ in the columellarian space, and opposite the arrow one of the primary septa is seen shorter than the others. In this interseptal space is seen a small clavate tube, around the inner margin of which, and contiguous to the inner margin of the primary septa, is seen a group of ovular bodies.

Fig. 5.—*Aspidiophyllum Cruciform.* Thomson. A transverse section, shewing the singular arrangement of the lamellæ in the columellarian space.

Fig. 6.—*Aspidiophyllum Hennedii.* Thomson. A transverse section.

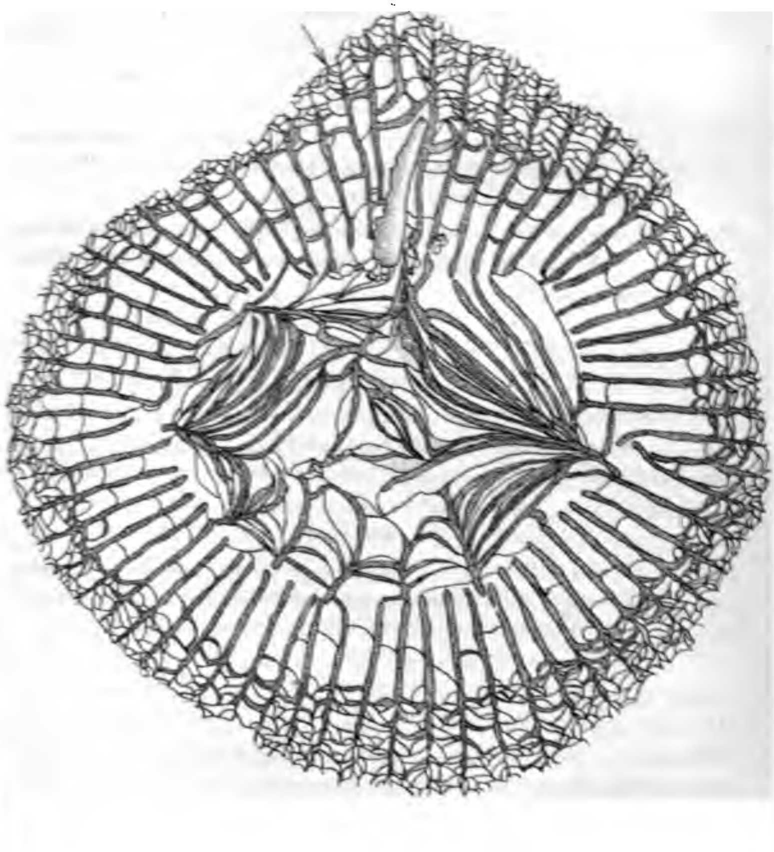
Fig. 9.—*Aspidiophyllum Elegans.* Thomson. Upper surface of calice, shewing the form of columellarian boss and the arrangement of lamellæ.

Fig. 9A.—A transverse section of the same.

The longitudinal section of Fig. 1, and all the transverse sections, are facsimiles of the sections.

PLATE II.

Fig. 1.—*Aspidiophyllum Huxleyana.* Thomson. Enlarged four diameters. Shewing the arrangement of ovular bodies and the diminution in numbers after the 500th part of an inch was ground away.



Carboniferous Corals.

To illustrate Mr Thomson's paper

XII.—*Address to the Chemical Section of the Philosophical Society of Glasgow, by the President,* EDWARD C. C. STANFORD, F.C.S.

[Read before the Chemical Section of the Society, Nov. 9, 1874.]

GENTLEMEN—Since I last had the honour of addressing you from this chair, we have sustained a severe loss—only a week since Dr. Thomas Anderson departed this life. Educated in the University of Edinburgh, where he graduated as M.D., he afterwards studied under Berzelius at Stockholm, and under Liebig at Giessen. He did full justice to the teaching of these great chemists, and was author of a number of most important researches. Amongst these, his researches on some of the opium bases, and particularly those on the bases of coal tar and bone oil, earned for him a high reputation amongst European chemists. Those only who have experienced the difficulties and dangers attending such an exhaustive research as that of Anderson on the coal tar bases and bone oil bases, can appreciate rightly the enormous amount of work involved. Mansfield had lost his life in a similar research; and any chemist who wishes to subject himself to penance should take up a research on some kind of tar: he will not only provide himself with work for life, but he will find that his friends prefer to keep him at a distance. Few who have not studied these researches would understand their practical value; but to those who would apply the "*cui bono*" test, I would remark that Anderson, though not the actual discoverer, was the first to fully investigate Anthracene, and under the name of Oxanthracene he actually described that remarkable oxidised derivative of Anthracene now known as Anthraquinone. This substance is the starting point in the manufacture of Alizarine—the colouring principle of madder—a vegetable colour which has so long defied the efforts of chemists to reproduce it in the laboratory. So that Anderson may be really said to have laid the foundation of one of the largest and most scientific of chemical manufactures.

His numerous researches earned him the distinction of Fellow of the Royal Society, and in 1852 he was appointed Regius Professor of Chemistry in the University of Glasgow, having previously been appointed Chemist to the Highland and Agricultural Society. These appointments he held to within a short period of his death.

He will be mourned by all chemists, as his fame was world-wide; but we ought to be the chief mourners. Some of my colleagues around me will remember that we did not organise this Section without considerable difficulty and even opposition in some quarters where we least expected it. Knowing the want of a Chemical Society in a city like this, where almost every known chemical manufacture is represented, we were much encouraged by the warm co-operation and assistance of the late Dr. Anderson.

We have been pained to see him the last year or two becoming enfeebled. He was our first President; and whilst all Europe mourns a distinguished and accomplished chemist, we miss his friendly advice and courteous demeanour to one and all of us, who mourn the man even more than the chemist lost.

I may congratulate you on the increasing prosperity of this Section. We have largely assisted the membership of the Society, and now there are no less than three other Sections added, resulting—as some day, I hope it may—in gathering all the Scientific Societies in Glasgow under one roof, and their proceedings into one book; and until that is accomplished, the *Proceedings of the Philosophical Society of Glasgow* will not properly represent the science of this city. I would wish to add that the reporting of the discussions in this and other Sections is open to great improvement: it is often the most important part of the meeting, and we have not the means of rendering it.

The recent meeting here of the Social Science Association has, by the appointment of Dr. Lyon Playfair as the President of the Health Section, given considerable prominence to the chemistry of health. The address of that eminent chemist was, as might have been expected, a masterpiece. In my opinion it is quite time the aid of chemical research should be called in to assist in this subject. It is remarkable even now how little we know chemically of the air we breathe, the soil we live upon, the water we drink, and the food we eat. The chemistry of Hygiene is quite in its infancy.

Pettenkofer avers that in all healthy houses we virtually live outdoors, the walls being largely pervious to air, and he shews that where these walls are saturated with water, as must often happen with the porous sandstone houses of this city, they become impervious to air, and therefore unhealthy. It has been found that to keep the air pure in houses a ventilation is necessary of more than 2,100 cubic feet per head per hour. This appears enormous, when it is remembered that an individual does not inhale and exhale more than 18 cubic feet of air per hour.

When the Model Hospital la Riboisiere was erected in the Faubourg Poissonnière, it was furnished with artificial ventilation: 700 cubic feet per head per hour was judged ample for all requirements. At this rate the air in the wards was quite foul, and it was not until 2,120 cubic feet were used that the hospital was pure. The rate now recommended is as follows:—

	Per Head per Hour.
In Hospitals for Ordinary Cases, . .	2,120—2470 cubic feet.
,, ,, Wounded, . . .	3,530 ,,
,, ,, Epidemics, . . .	5,300 ,,

Pettenkofer shews that most of the ventilation of a room is through the walls, and we are apt to forget how extremely porous to gases these septa generally are. He reckons the average rate per square yard at about 7 cubic feet, or 43 gallons per hour.

He employs carbonic acid measurements in these researches; and the large wall ventilation shews that smaller houses have more ventilation, in proportion to their size, than large ones. In earth hovels the ventilation is about 14 cubic feet per hour, or double the average rate, owing to the greater porosity.

His researches generally are most interesting; and when we consider the number of germs of disease often in the air, we must confess that our air chemistry is sadly at fault.

Turning now to the soil we dwell on, we should not forget that our houses are practically, if well drained, built on air, or rather on soil full of air, and we know if this soil be full of water our health suffers. The porosity of soil to air and gases is so remarkable, that Pettenkofer relates cases of "persons poisoned and killed by gas which had to travel for twenty feet under the street, and then through the foundations, cellar vaults, and flooring of the ground-floor rooms." The porosity of the soil has an important effect on the decomposition of corpses; it has been shewn that in a porous soil the body rapidly decays, whereas in a clay soil it is preserved for long periods; and it shews the necessity for proper investigation before deciding on sites for cemeteries—unless we are to make our relations into gas, and thus "live by the light of our ancestors," as Dr. Lyon Playfair has suggested.

Turning to the water we drink, there is still, unfortunately, great difference of opinion as to the proper composition of a good drinking water. The term "previous sewage contamination" which has been introduced is misleading, because some of the deep-well waters will shew large amounts of nitrates without a trace of organic

matter—and it does not follow that these nitrates have been derived from sewage.

On the other hand, our own celebrated Loch Katrine water contains nearly as much organic matter as that of the best London supply; and there is no doubt, to be entirely free from all suspicion, this organic matter should be separated by filtration.

Professor Wanklyn's method of water analysis has given us great facilities in easily assessing the value of a drinking water, and his manual on the subject should be in the hands of all analysts; for the analysis of drinking water is now constantly required.

The amount of ignorance which generally prevails on this subject is extraordinary; it is impossible to convince healthy villagers that they have long been in the habit of drinking a dangerous water—and the analyst must always expect great opposition to his statements. In one case in Scotland where a good water supply was voted against, I took the trouble to inquire the reasons of two voters. One said the engineer knew nothing about it, because he had got one 6-inch pipe to supply two 4-inch pipes, which was impossible; the other said that the engineer couldn't have laid down the pipes right, because he hadn't measured the ground, forgetting that the ordnance map very accurately supplied him with the data. How can such people judge of the analysis of a water?

The question of water supply naturally leads us to the consideration of that supply after our houses have fouled it into sewage. The President of the Health Section of the Social Science Meeting summed up the processes for dealing with this question into the one old law, "Wash and be clean." This is applied to individuals and to houses; as to manufactories, he advocates another law, "Thou shalt not pollute rivers,"—thus evidently advocating interception. I have always been strongly of opinion that these two laws must some day be enforced upon us. If we have only to deal with the water supply before and after it leaves our houses, we deal with a definite fixed quantity so comparatively small that it is easily dealt with. At present, however, the sewage of towns contains also that very variable item, the rainfall; and whenever this has to be included, it upsets all systems of filtration, irrigation, &c., because in time of floods it must be run to the nearest river. If the water-closet system is to be continued, it must be carried out in a separate system of impervious sewers; and if it is to be utilised, that result must be attained before the assistance of chemists is called in.

As long as the value of the material to be utilised is only one penny per ton, we must leave the towns to the tender but expensive

mercies of the engineer. As for irrigation, farmers in the west of Scotland do not, as a rule, complain for want of water, and, as far as I know, would prefer their manure dry—certainly not in that extraordinary state of dilution which characterises the Glasgow sewage, which is only about two-thirds the average value.

Bad as our river is, we have had more processes brought before the authorities here than anywhere else; three of these are at present little known elsewhere.

I allude to Mr. Chapman's method of utilising the urine of the city, to the Hoey limited water-closet system, and to the carbon closet system. An interesting report on these processes, by Dr. Wallace, has been published by the Glasgow Police Board. All these processes are those of interception, and are all steps in advance, because all are utilising what has hitherto been waste and polluting material. Any method of keeping valuable pollution out of the sewers ought to be encouraged, because by so much it lessens the difficulty. The question will probably ultimately resolve itself into this—that all polluting material must be kept out of the sewers, manufacturers must look after their own pollutions, and householders after theirs, the town looking after the rainfall and streets. Taken at the outlet, the question is extremely difficult; taken at the house, it is easy; and house to house purification may become the real solution of the difficulty.

Before leaving the subject of sewage, I would say a few words on disinfection; the public appear to me to be altogether on the wrong tack. Chloride of lime and carbolic acid are making our cities everywhere offensive; both these substances act well if concentrated: they act like the clear, sharp cut of the surgeon's knife, but they do not bear dilution. Both substances when dilute have been found actually to favour the growth of germs, and it cannot be too generally known that the universal use of these substances to overcome bad smells is simply substituting one stink for another. There is nothing more difficult than the purification of infected air. A good disinfectant should not itself foul the air it pretends to purify. The only true way to disinfect is to prevent decomposition. We have several old antiseptics which ought not to be forgotten. Dr. Angus Smith has shewn that common salt is much cheaper and better than these popular and odoriferous remedies. I have strongly urged the use of chloride of calcium for this purpose. It is the cheapest of all disinfectants, and could be got in enormous quantities.

The food question leads us to the consideration of the Adulteration of Food Act. This has given rise to a large number of appointments to chemists as local analysts. Unfortunately, our science has not hitherto come well out of the sudden demand on it. In the first place, the appointments were so numerous that we had not the men; and there is no doubt that our processes for the detection of adulterations in food were very crude and immature. These, however, are merely temporary difficulties. Wanklyn in his series of food researches has shewn that milk, tea, coffee, and cocoa can be accurately tested; but these are but a small portion of what comes under the public analyst's attention. The position not only requires high analytical ability, but a large knowledge of the trades in food products.

The subject of commercial analysis has been brought before you during the past session. The great discrepancies between different analysts, which have given rise to the very objectionable titles of "high and low chemists," have been a scandal to our science. With a view of making some reform, we agreed to petition the British Association to appoint a Committee to inquire into the methods of testing potash salts and phosphates, those being the substances in which we had noticed the greatest variation, and, if possible, arrive at standard processes of general application, and agree as to statement of analytical results. We applied also to the Newcastle Chemical Society to support us in the application. They held a special meeting on the subject, and warmly supported us, adding in their resolution the following substances:—copper, soda, and sulphur. Shewing how strongly they felt in that large centre of manufacturing chemistry, they also passed the following resolution: —"And that this Society is of opinion that the sub-committee suggested might also usefully inquire into the question of instituting a professional examination for a diploma, without which no person should be legally qualified as a public analyst." This resolution was soon after given effect to in a meeting of public analysts held in London, under the presidency of Dr. Redwood, and where resolutions were passed almost identical. These chemists had been roused to action by the suggestion of the Committee on Adulteration, that the Inland Revenue Laboratory should be the ultimate court of appeal in disputed cases. The Adulteration of Food Act has done much good; and when it is, as it will be, regulated by the analyses of accomplished chemists, working by accurate chemical processes, and not by microscopic medical men, it will be a great boon to the nation. The British Association

appointed a committee with a grant of £10 to meet our wishes, and inquire into potash salts and superposphates.

The Committee consists of Dr. Dewar, Messrs. Fletcher, Allen, and Stanford, with power to add to their number—Mr. Allen being Secretary. We have already received several letters shewing how much such a Committee was required, and we hope before next year to report at any rate on the processes usually adopted.

I fear we cannot congratulate ourselves on the progress of original research during the past year. We have no transit of a chemical Venus to do for our science what will be done for Astronomy this year. Professor Grant, in his presidential address, has reminded us, however, that for any chemist who is tired of the earth there is the sun to work on. Our accurate knowledge of most of the materials surrounding the sun shews that our chemical methods are not now limited to the earth; and it is open to any aspiring genius to discover the unknown element that gives rise to the bright green line in the sun's spectrum. It is unnecessary now to go there for the purpose. One of the most remarkable discoveries of the year is that of Tiemann and Haarmaan, who have succeeded in splitting up the glucoside coniferin into glucose and a white crystalline substance, which is identical in every respect with vanillin, obtained from vanilla. A manufactory has been established in Germany to thus prepare artificially this hitherto expensive natural product.

The Society of German Ultramarine Manufacturers have offered a prize of one thousand imperial marks for the best work on the constitution of ultramarine, and the exact form of combination in which the sulphur exists. If any of our members think of taking up this research, I would point out that many of the sulphur compounds with alkalies are undefined. No perfect explanation has yet been given of the curious colour changes in the evaporation of caustic soda, from dark red to green and blue, before actual fluxing. I would also remind those who wish "something to tusslo with," that artificial quinine is yet undiscovered, and that our late President has left a splendid legacy to any of us who would follow his opium researches, and reproduce the active principles of that important drug. We know very little about the real causes of nitrification. I have shewn that neither charcoal nor earth oxidise ordinary nitrogenous organic matter, and that the latter simply produces decay and evolution of ammonia. In solution the action of various filtering media on nitrogenous organic matter is very imperfectly understood. I shall have some experiments on this

subject to bring before you during the session; but I would only premise here that filtration through porous bodies tends to convert the nitrogen into ammonia rather than, as generally supposed, into nitric acid. We may, I hope, look to our newly appointed Professors of Chemistry in this city for many original papers. They are all young, and they follow men who have been very eminent in this respect. I appeal to them to shew us that original research is not dead here.

Those engaged in the manufacture of chemicals have enough to do now to hold their own against foreign competition. Where elaborate chemical processes are required—as, for instance, in the preparation of the natural alkaloids—we cannot compete with the German manufacturers, who, with the exceptions of quinine and morphia, have this class of manufacture mostly in their own hands. We cannot secure sufficiently educated workmen for this high class of work. One of the most important contributions from the laboratory to medical science is chloral hydrate, the first narcotic artificially produced. This substance, for which there is now an enormous demand in medicine, is almost all imported. Our manufacturers in this and in the alkaloids are also handicapped by the large duty payable on alcohol in this country. We can obtain methylated spirit free of duty for manufacturing purposes; but unfortunately this is an impure spirit, and unsuitable for the preparation of pure chemicals. The object of this admixture was to prevent the use of this spirit for drinking; but seeing that it is easily "cleaned," and that even in the rough state it is largely sold and readily bought for this purpose, the object desired has not been attained. As the use of this spirit entitles the excise officers to visit the works, it appears to me that it would be very much better to allow the use of pure spirit in all chemical works under certain restrictions.

Another important anodyne medicine contributed from the laboratory is bromide of potassium. The consumption of this medicine is now considerable, and daily increasing—so much so, that our ordinary resources would have failed to meet the demand. The large amount, however, imported from the German potash mines, and from America, enables us at present to keep up the supply. Iodine, hitherto obtained only from sea-weed, is now largely imported from Chili, extracted from the mother liquors of the Chilian caliche, after separation of the nitrate of soda. Large quantities are said to be procurable from this source. The supply exceeds the demand, and now a new outlet for iodine is looked for.

It is said that at a low price it would be largely used in the steel works.

The German source of bromine has enormously increased our supply of potash. At one time our supplies were limited to the potash salts from sea-weed, the saltpetre from India, and the potashes and pearlashes from America. We are now large exporters of both saltpetre and pearlash. The natural supplies of the latter have largely fallen off, and before long may cease altogether. Obtained from the ashes of forest trees, the manufacture of pearlash decreases with the spread of civilisation. The new supply from the German and other mines is far more important than all the other sources put together; but the demand is gradually approaching it. The great importance of potash as a manure is only beginning to be appreciated. The ashes of all our principal foods are remarkable for the large proportion of potash they contain. The most exhaustive crops are those which, as a rule, contain the most potash. Agricultural chemists have not generally placed a sufficient value on this ingredient of manures, but no manure is complete without it; and it is as important to almost any crop as ammonia. Soda does not in the least replace it; and yet the beet-root producers of France have exported potash as part of their produce from the beet—a suicidal measure, it would seem, as it ought to be returned to the soil.

In our great staple chemical industry—the manufacture of soda ash, the process of Le Blanc still holds its own in this country. Everyone admits that the process is roundabout, and has many disadvantages, and yet no more direct method has yet superseded it. We are threatened, however, by more than one process, especially abroad, where the oldest rival has recently appeared, under the name of the ammonia process. This was originally introduced a long time ago by Hemmingway, who took out a patent for the manufacture of bicarbonate of soda (a salt not so easily produced then as now), and which realised then a high price compared with carbonate of soda, and the soda manufacture was in the hands of a chosen few. The method was a decomposition of chloride of sodium by bicarbonate of ammonia. The decomposition is perfect, or "nette," as the French chemists say—a word for which we have no translation; but the company formed to work it failed, I believe, from the difficulty of washing away the two salts. Some foreign patents, and one by our distinguished citizen, James Young, have improved this process as a means for making carbonate of soda; and although it has not made much progress in this country, it is said to be largely

used abroad, and we are threatened with great opposition from it. Deacon's process of dissociation of hydrochloric acid is another great step in advance. The direct attack of sulphate of soda by baryta salts, is another which may any day become a formidable opponent of the present method.

It appears to me, however, that the most promising improvement is that of Hargreaves and Robinson, who decompose the chloride of sodium direct by sulphurous acid from the pyrites burners: they thus do away with the wear and tear of vitriol chambers, and produce sulphate of a high degree of purity.

Large works are being erected in Lancashire for this process. I hope during the present session some of our members, who are quite competent to discuss these improvements, will bring them before us. One of the new improvements in manufactures that appear to me very valuable is Morfit's method of making soaps direct from the combination of the fatty acid and the carbonated alkali, thus making a soap direct without the expense of causticising the alkali, and the prolonged boiling necessary to decompose the oil or fat employed, and the loss of the whole of the glycerine. He has written a most elaborate and costly work on the subject; but I am not aware that the process is practically worked. We have several eminent soap-makers amongst our members, and I hope some one of them will give us a paper on this subject.

In our own alkali manufacture many improvements have been introduced. One of the most notable, perhaps, is the revolving black ash furnace, which economises labour. Labour and fuel are very important elements in the manufacture of soda ash, the raw material being low in value. In potash working the waste is the most important consideration, the raw material being expensive.

The utilisation of waste is still the most important of chemical questions. Weldon's process of manganese recovery and Mond's process of extraction of sulphur, are valuable steps in the right direction, and each can be worked with a profit; but they are only steps, and neither can yet be considered perfect. I cannot leave this question without referring to the process of one of our members, Mr. Mactear, which appears to me a great improvement, and is now in work at St. Rollox. He employs the sulphurous acid gas from pyrites for the oxidation of the yellow liquors, which are then decomposed by muriatic acid, thus obtaining both the sulphur of the waste and also of the pyrites. He is enabled also to take advantage of the natural rainfall, and simply use the liquor draining from

the very large stock of waste which Messrs. Tennant & Company have in reserve.

Manufacturers may expect next year an amendment of the Alkali Act. I do not know if the 5 per cent. allowance of hydrochloric acid escaping will be reduced, but I think it ought to be. Half this would appear to me not unreasonable. Certainly sulphurous acid will be included in the new law, and it ought to be, for I am convinced, from personal observation, that sulphurous acid is more destructive to crops than hydrochloric acid.

Under the new laws we shall have to be more and more particular in our chimney testing. It is unfortunate that although we can easily determine the gases in a cubic foot of the air passing up our chimneys, it is exceedingly difficult to ascertain exactly how many cubic feet pass per minute—I have tried every apparatus yet introduced, but none appear to me quite trustworthy and satisfactory—in working on such a variable rate as that of a chimney. As to the testing of the chimney, in our own works I employ a simple apparatus, which is not generally used, but which I can thoroughly recommend. On a platform, about twenty feet high, we have a box of stout lead, of exactly a cubic foot capacity. It is arranged with a tap near that can be used to fill it with water; when filled, a tube on the top is attached to Woulff's bottles, containing the solutions through which the gas is to be drawn; a cock at the bottom is then opened, and the water allowed to run off—thus drawing through the solutions exactly one cubic foot of gas. In the ordinary alkali inspector's bellows this requires eight exhaustions. The operation is very tedious and inaccurate. We test thus twice a day for hydrochloric acid, sulphurous acid, potash, and ammonia.

Our manufacturers may hope for a better class of workmen from the technical colleges which are now springing up over the country. In the Yorkshire College of Science, now commencing its first session, the Clothworker's Company of London have founded eight Studentships—four of £30 each, and four of £25 each. I hope this example will be largely followed in our new Technical College to be established in this city, and that ere long our workmen will be as much renowned for their scientific and technical knowledge as they are for their power of doing hard work. Our working classes are generally superior to others, so far as the actual amount of work they can do is concerned, and it is our duty to put them on the same level as their competitors abroad. I have no fear of retaining our supremacy if we cultivate heads as well as hands.

In inaugurating another session, I would again remind you that we shall be glad to receive laboratory notes, or incomplete papers, on any novel phenomena. Indeed, I would repeat what was stated in my last address, that a paper describing failures would be most instructive. I hope that all will give us the benefit of their observation and experience, and endeavour to make the session to-night inaugurated excel all those which have preceded it.

XIII.—*On the Apparent Absence of Air and Water from the Moon.* By Mr. FRANCIS NAPIER. Communicated by Mr. JAMES R. NAPIER.

[Read before the Society, December 2, 1874.]

1. THAT the surface of the moon is devoid of both air and water, at least, that neither can be detected by the most delicate observations, is a fact admitted by all who have made our satellite the subject of their special study.

If the earth and moon originally formed part of the same nebulous mass, it seems inexplicable that what is so abundant in the one should be absent in the other; and it is the object of the present paper to endeavour to shew that, notwithstanding the admitted fact that neither air nor water can be at present detected on the moon's *surface*, it is quite within the range of possibility, if not highly probable, that both may have existed on the moon's surface as atmosphere and ocean to an equal degree relatively to its size, that they do on our earth; but that they have now disappeared from the surface and gone into the *interior*, leaving no visible trace behind.

2. We assume that the moon, equally with the earth, has been in a molten state, and for incalculable ages has been cooling till it arrived at its present temperature. This is an assumption so generally admitted that nothing further need be said upon it.

3. In the process of cooling the *outer shell* must first have become solid, the thin crust cracking and yielding to the contractile force of the cooling mass, but continually thickening and becoming stronger, so as to be able to resist more and more the crushing force.

4. As the pressure caused by the gravitating force of a thin spherical shell on the particles of which it is composed diminishes with the diameter of the shell, and therefore the average crushing force diminishes with the thickness; and the power to resist the crushing force increases in a high ratio to the thickness, becoming, in fact, almost infinite long before the whole mass becomes solid, there must be a given thickness of shell at which it will resist all further contraction. What that thickness would be is of course

matter of conjecture, and would depend on a variety of circumstances which it is unnecessary to enumerate here.

5. When it has attained this thickness all further cooling of the interior mass must necessarily result in the formation of cavities and hollows, like a honeycomb, the solid parts remaining as walls or ribs and buttresses, thus strengthening and stiffening the outer shell, and enabling it still further to resist the enormous pressure to which it would be subjected.

6. These chasms and caves would increase in volume in the ratio of the contraction of the interior mass of molten matter after the outer shell had become fixed. The amount of this contraction would depend (1.) on the thickness of the external shell, (2.) on the total reduction of temperature from the time the outer crust became rigid, and (3.) on the ratio of heat-expansion of the materials of the moon's nucleus.

7. As these are points on which we have no data, for the sake of argument they may be assumed. Suppose the moon's crust to have solidified to a depth of 200 miles (or one-fifth of its radius) before it became sufficiently rigid to resist all further deformation (and it cannot well be conceived how a spherical shell of this thickness could crumple up under any equally distributed pressure normal to the surface). It may also be taken for granted that the ratio of heat-expansion of the materials of the moon is about the same as that of the rocks composing the solid parts of our globe.

8. The moon's volume being something over 5,000,000,000 of cubic miles, deducting from this the solid shell (as above supposed to be 200 miles thick) there will remain more than 2,500,000,000 of cubic miles of liquid matter in her interior to become consolidated.

9. The amount of reduction of temperature after the outer shell has become fixed may be taken for argument's sake at 400° Fahrenheit (it might be many times this amount). The contraction consequent on this refrigeration, which may be safely taken at the same rate as that of terrestrial rocks, would be at least $\frac{1}{300}$ part, or more than 8,000,000 of cubic miles, which must necessarily appear in the form of hollows and caverns in the interior, communicating with each other by cracks and fissures, and with the surface by means of innumerable volcanic vents and craters existing there.

10. Into these hollows the water that was on the moon's surface would necessarily disappear, and there would be room enough for an ocean quite as large in proportion as the earth's—one that would cover half the moon's surface one mile deep, with nearly a million miles to spare—and this without taking into account the compres-

sion and consequent reduction in volume, caused by the enormous hydrostatic pressure to which the water would be subjected (at a depth of 600 miles it would be reduced to nearly half its volume).

11. Having disposed of the ocean, the disappearance of the atmosphere offers no difficulty. Supposing the moon to have originally possessed an atmosphere bearing the same ratio to its mass that ours does to that of the earth, it is easy to calculate that the lunar atmosphere would exert a pressure on the moon's surface of about five inches of mercury. But five inches of mercury on the moon's surface would be equivalent to about five-sixths of an inch on the earth, which would therefore be the atmospheric density at the moon's surface.

12. The bulk of a homogeneous atmosphere of this density would be about 436,000,000 of cubic miles. This air would rush into the spaces unoccupied by the water, doubling in density at first every 20 miles of depth that it penetrated. At a depth of about 300 or 400 miles it would have the density of water, when the whole of the atmosphere could be compressed into 13,000 cubic miles; and there is no reason to suppose that air may not be compressed even to the density of *mercury*, when a cavity of 1000 cubic miles would contain the whole.

13. Thus the writer has attempted to shew, by means of ordinary well ascertained physical laws, that it is possible for a lunar ocean and atmosphere to have at one time existed, and yet, in the course of incalculable ages, they might both disappear from the surface into the interior, leaving no measurable trace behind.

DISCUSSION ON MR. F. NAPIER'S PAPER.

After the paper was read a question arose as to the compressibility of water—viz., whether it was as great as stated by the author of the paper. To this he replied that the deductions drawn would hold even if water were perfectly incompressible, but that various physicists had shewn that the compressibility of water up to 220 atmospheres is $\frac{1}{20,000}$ of its volume per atmosphere.

It was then remarked that it was possible, if not probable, that the water would be converted into ice. With this the author of the paper agreed, adding, however, that it would not affect his argument.

Mr. Coleman affirmed that however deep the cavities in the moon might be, there must still remain a small quantity of air of low density on the surface.

Mr. Muir remarked that if the argument was applicable to the moon, it was equally applicable to the earth, and that, therefore, the paper ought to be viewed as *prophetic.*

To the last two remarks the author assented.

XIV.—*Experiments on Fluid Jets and Induced Currents.* By Mr. ALEXANDER MORTON.

[Read before the Society, December 2, 1874.]

DURING the experiments which led me to the "Ejector Condenser" I had at times occasion to make great variations in the form of apparatus used, as well as in the water and steam pressures under which the experiments were performed; and as I believe many of them are new, I now offer to the Society a description of the most noteworthy, which may be useful to others who may follow a similar course hereafter.

The drawing, Plate I., shews some of the forms of apparatus used, which along with this paper may convey to you more fully the nature of the several experiments performed and the results obtained. The apparatus shewn in section by fig. 1, consists of a simple conoidal nozzle screwed into the body of the inlet or supply tube, which nozzle, when supplied with a head pressure of water of from 8 to 10 feet, discharged a jet vertically to within 1 foot of the height of the supply level, when there was little or no rotary motion in the jet on leaving the nozzle. To prevent this revolving motion I used a cross piece, shewn in plan, fig. 2, in the wide end of the nozzle, as I found it almost impossible to get steady results without it. Water falling freely through a tube, although perfectly straight and free from any knees or bends, has always an inclination to revolve in some direction in its onward course, and often leaves the nozzle with such a velocity that the jet becomes broken into spray at a short distance from it. Certain knees and bends so increase the revolving motion, that the centrifugal force on issuing from the nozzle may nearly equal the impelling forward force of the jet; hence the necessity of a "cross piece" in every experiment, as steadiness and accuracy are of the greatest importance in obtaining definite results. With the apparatus, fig. 1, suspended by a flexible India-rubber tube, as shewn by fig. 9, the reaction of the jet may be approximately obtained by measuring the angle to which it has been deflected; but in my experiments, to obtain the greatest deflection with a given area of nozzle was my

sole aim. To define the exact reaction of a given jet formed no part of these experiments; but when the "cross piece" was in place, the simple conoidal nozzle, delivering freely into the atmosphere, gave the greatest reaction, and the impelled jet rose to the greatest height. The apparatus, fig. 3, has a very large conoidal nozzle, within which and truly concentric therewith is fixed a central tapering spindle of somewhat less diameter than the smallest diameter of its nozzle, thus forming an annular nozzle. With such an apparatus, having an annulus of greater area than that of the simple nozzle, fig. 1, the issuing jet may not rise to one-half the height when supplied from the same head of water, even although increased in area, until it delivers the same quantity of water in a given time. The reaction of such a jet is also proportionally less; and when the annulus is of great diameter compared with that of the simple nozzle, the discharge becomes so reduced in quantity that a worse form of nozzle in retarding the delivery can scarcely be conceived; still, there is in my opinion a worse form in use. I here refer to ordinary safety valves of steam boilers, which are not only very large annular nozzles, but are often so constructed that the steam has to turn abruptly into a direction at right angles to itself on escaping. The lift of these valves is generally very small compared with their diameter, consequently the thin film of steam must be more retarded in escaping than in any of the annular nozzles I have experimented with; therefore, with our present knowledge, unless by a mere guess, we could not say within probably 50 per cent. of the weight of steam that would pass through them. I am not aware of any authentic experiments on the subject; but I know that witnesses at coroners' inquests, &c., generally take the area of the annulus multiplied by the velocity and density as the probable delivery. The experiments just described tend to quite a different conclusion; and I think we now ought to know how the different lifts of ordinary safety valves effect the delivery of steam through them.

The apparatus shown by fig. 4 has a trumpet-mouthed discharge-tube, the narrow end or throat of which is of exactly the same form and size as the simple nozzle, fig. 1; and when supplied from the same head of water it will deliver more than double the quantity of water in a given time of that issuing from the simple nozzle; therefore the velocity of the jet at the throat must be also more than double, as the areas of both are exactly equal. It may be asked, why such an increase in quantity? in answer, I can only say that I account for it through some unknown or not yet satis-

factorily explained action of the enlarging jet. This action we can see going on within the tube, and can prevent it by greasing the internal surface when water is the fluid passing through it; but within such a tube there lies a secret, which may be explained hereafter. I had newly finished a gun-metal tube which I considered of a better form than any I had previously tried, and having polished the inside of it first with fine emery and oil, and then with crocus and oil, it was therefore, although smooth, very greasy, and on experimenting with it I became bewildered at the inferior and unsteady results; but on substituting an old tube not greasy, immediately the delivery increased and the results became steady as usual, thus proving the fault to lie in the greasy tube.

I have said that with about 9 feet head more than *double* the quantity of water would be delivered; but, on lowering the head, thereby reducing the water pressure, a still greater quantity will issue, even as much as three to four times that delivered through fig. 1, with the same head. Near the throat of the discharge tube there is a constant vacuum, so that the jet of water rushing through the throat attains the velocity due to the head plus the vacuum; whereas with the simple nozzle, fig. 1, the greatest velocity through it can only be that due to the head alone minus the friction. When this apparatus is suspended by the India-rubber tube, fig. 10, although the delivery is so great compared with fig. 1, its reaction is almost nil, and the discharge jet falls as it were dead on leaving the discharge tube; whereas with the simple nozzle the jet may spout out many *yards* horizontally in an unbroken, nearly solid stream; here therefore is an action we can so arrange that the jet force may be wholly absorbed within two or three inches of a smooth discharge tube. From these two experiments we may safely infer that the jet within the discharge tube must have performed some great work before it was finally discharged, and although of double the velocity at the throat, it may fall without force at the wide discharge end.

Fig, 5 is an apparatus constructed so as to measure the vacuum at the throat of the discharge tube. The inlet water enters by the passage A, and passes first through a simple nozzle of the form and dimensions of fig. 1; the nozzle and the throat of the discharge tube are of exactly the same diameter, a truly cylindrical steel mandril being the gauge in all the experiments—consequently the discharge tube and nozzle may be said to be one tube cut through at the throat. The passage B is directly connected with a straight glass tube dipping into a dish of mercury, and so soon as water

flows through the apparatus the mercury rises in the glass tube, which can readily be noted; and with a clean discharge tube, not greasy, of the form shewn on the drawing, with water at about 50° Fahrenheit or lower, having a head of about 2½ lbs. pressure per square inch, a vacuum nearly equal to that due to the barometrical pressure at the time may be obtained. I may here add that highly heated water issuing from a steam boiler through this apparatus produces a partial vacuum in the passage B, and the mercury has risen in some experiments 8 inches. The apparatus represented by fig. 6 consists of a conoidal nozzle, somewhat similar to that just described, but its area of opening may be regulated by a central adjustable spindle, so far similar to a "Giffard Injector."

This nozzle is concentric with another nozzle immediately in front of it, somewhat of the form shewn by fig. 5. It has a throat, and widens gradually towards the discharge end. Steam is the impelling fluid in this experiment, and enters by the passage A, thence through the first nozzle. The passage B, instead of communicating with the mercury, as in the previous experiments, leads to cold water, a foot or thereby below the level of the apparatus—the distance may vary to ten feet below the apparatus, as no great nicety is required up to that distance. The steam rushing through the central nozzle induces and carries the air with it, thus causing the water to rise and enter the apparatus surrounding the steam jet in an annular form which, on meeting the steam, is impelled forward with it exactly as in "Injectors" for feeding steam boilers, only the combining or discharge tube in this apparatus is of the form shewn on the drawing, C is the discharge or overflow passage. In the very centre of this discharge tube I introduced a very fine receiving nozzle and tube, D, which are adjustable. This receiving tube, D, has a prolonged tube, extending from the other end of the apparatus, with a coupling, so that either a pressure gauge or a vacuum gauge may be used, as the experiments require. To ascertain what takes place in the very centre of the combined steam and water jet, this fine receiving nozzle D, could be adjusted and brought so near to the steam nozzle that steam alone acted in it; then, by gradually taking it farther from the steam jet, so as to receive the mixed water and steam, or the condensed steam alone, the pressure was registered by the pressure gauge in connection with it; and I found that just immediately in front of the steam jet, where the water and steam may be said to coalesce, that a steam pressure of 5 lbs. per square inch above the atmosphere produced 40 lbs. per square inch in the receiving tube, and with 40 lbs. steam pressure upwards of 300 lbs.

per square inch was indicated by the gauge in connection with the central receiving tube, how much more I did not have the means to determine, as my gauge was at its highest limit; but on moving the central receiving nozzle less than one-sixteenth of an inch nearer to the steam nozzle, the pressure fell to nothing, and by substituting a vacuum gauge for the pressure gauge, I found a vacuum of about 8 lbs. per square inch, just in front of the issuing steam jet of 40 lbs. pressure per square inch above the atmosphere. Here then, in the very centre of this apparatus, a préssure of upwards of 300 lbs. per square inch is registered when the receiving tube is in a position not one-sixteenth of an inch from the position where all pressure had ceased, at least had become reduced to 8 lbs. per square inch below the pressure of the atmosphere.

The apparatus represented by fig. 7 consists of a conoidal nozzle and regulating spindle, so far exactly the same as the apparatus just described; but the discharge tube, instead of widening towards its delivery end, in this experiment the tube contracts to a less diameter than either of the nozzles. That part containing the receiving nozzle and pressure gauge is shewn unscrewed and slightly removed from its position, as it is only required in place when registering the pressure. Steam is admitted by the passage A, and water of the same temperature and pressure is admitted by the passage B. The steam pipe communicates with the steam space, and the water pipe with the water space of the same boiler. When in operation globules of water are propelled with great force and regularity without condensing the steam, which escapes at the overflow passage after ejecting the now elongated globules of water. These elongated globules become so equally divided, that the ear cannot detect a difference neither as to time nor quantity discharged at each beat. Now the ear is a very sensitive indicator, which can detect a difference in the beats of a locomotive whose valves have been most carefully set; but with this apparatus, under a nearly constant boiler pressure, it was impossible to detect a difference in the beats. It appears to me, that whilst the steam is propelling the contracting globule of water through the tapered tube, and until it is finally discharged from it, the water from the boiler does not enter the apparatus. Again, when a column of mercury takes the place of the water it becomes divided into globules exactly the same as with the water; but on entering the receiving tube a much higher pressure is registered. But to propel liquids in equal elongated globules the discharge tube must contract towards the outlet, so as to gradually reduce its diameter, thereby forming a liquid piston,

which prevents the steam from passing between it and the inner surface of the tube. With a parallel discharge tube, like a gun barrel, the steam and water rush out together very irregularly; but when shot is used instead of the water or mercury, although the head pressure of the shot is greatly inferior to the pressure of the steam, each shot is blown through a parallel tube separately, and as regularly as the liquid globules. In converting the apparatus into a model steam gun, fig. 11, the shot enters and passes through the central conoidal nozzle, the diameter of each shot ball nearly filling it. The central spindle is of course removed, and the steam is admitted through the annulus surrounding the nozzle. With this apparatus, fig. 11, the shot balls may be directed to any point within range, and may be guided to that point as exactly as a stream of water from a fire-engine nozzle. With a very high pressure of steam, a large but similar apparatus might be found to be a very destructive weapon.

Discussion on Mr. Morton's Paper.

Professor Jas. Thomson expressed his surprise at several of the results given in the paper, referring more particularly to those obtained in the attempts to measure the vacuum at the throat of the discharging nozzle, and seemed to think that confirmatory experiments were requisite. He also differed from the author in reference to the action of the enlarging jet (fig. 4), the theory of which, he thought, was perfectly well understood. Then digressing to an allied subject, he shewed several diagrams in illustration of various forms of *jet-pump*, of which he claimed to be the inventor, and which had been described in the Report of the British Association Meeting at Belfast many years ago.

Mr. R. D. Napier differed from Professor Thomson, and said that he did not find any difficulty in believing that the primary action of a head of 6 feet or less of water could produce a vacuum of 30 inches of mercury; for though that result was by far the best he had ever heard of, and was probably within a little of the best result practically obtainable, yet, in a theoretical point of view, it was by no means a remarkable result, for there was no theoretical limit to the smallness of the head by which a perfect vacuum might be produced in the throat of a discharging nozzle.

MR. DEAS stated, in reply to Mr. Mayer, that the system of jet-pumps at work in sinking the tri-une groups of concrete cylinders for carrying the quay walls of Stobcross Docks, was the invention of Mr. James Robertson, Glasgow.

It excavated the sand from the bottom of the cylinders by means

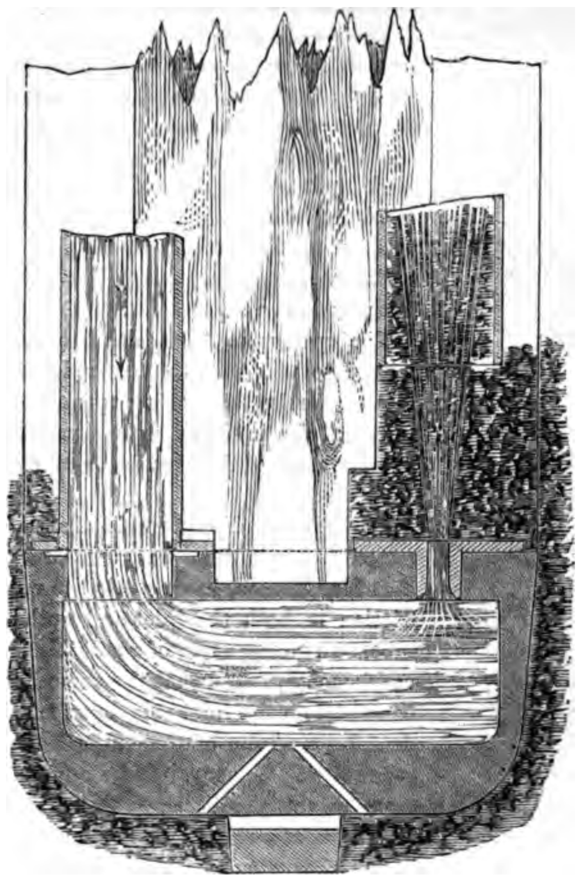


Fig. 1.

of a current of water forced down a pipe into a jet box wedge-shaped, so as to press into the sand, thence through an orifice on the top of the box, having a sectional area of about a fourth of the down pipe. The force with which the water issues from the orifice carries it into an upthrow pipe, the end of which is removed some

which prevents the steam from passing between it and the inner surface of the tube. With a parallel discharge tube, like a gun barrel, the steam and water rush out together very irregularly; but when shot is used instead of the water or mercury, although the head pressure of the shot is greatly inferior to the pressure of the steam, each shot is blown through a parallel tube separately, and as regularly as the liquid globules. In converting the apparatus into a model steam gun, fig. 11, the shot enters and passes through the central conoidal nozzle, the diameter of each shot ball nearly filling it. The central spindle is of course removed, and the steam is admitted through the annulus surrounding the nozzle. With this apparatus, fig. 11, the shot balls may be directed to any point within range, and may be guided to that point as exactly as a stream of water from a fire-engine nozzle. With a very high pressure of steam, a large but similar apparatus might be found to be a very destructive weapon.

Discussion on Mr. Morton's Paper.

Professor Jas. Thomson expressed his surprise at several of the results given in the paper, referring more particularly to those obtained in the attempts to measure the vacuum at the throat of the discharging nozzle, and seemed to think that confirmatory experiments were requisite. He also differed from the author in reference to the action of the enlarging jet (fig. 4), the theory of which, he thought, was perfectly well understood. Then digressing to an allied subject, he shewed several diagrams in illustration of various forms of *jet-pump*, of which he claimed to be the inventor, and which had been described in the Report of the British Association Meeting at Belfast many years ago.

Mr. R. D. Napier differed from Professor Thomson, and said that he did not find any difficulty in believing that the primary action of a head of 6 feet or less of water could produce a vacuum of 30 inches of mercury; for though that result was by far the best he had ever heard of, and was probably within a little of the best result practically obtainable, yet, in a theoretical point of view, it was by no means a remarkable result, for there was no theoretical limit to the smallness of the head by which a perfect vacuum might be produced in the throat of a discharging nozzle.

MR. DEAS stated, in reply to Mr. Mayer, that the system of jet-pumps at work in sinking the tri-une groups of concrete cylinders for carrying the quay walls of Stobcross Docks, was the invention of Mr. James Robertson, Glasgow.

It excavated the sand from the bottom of the cylinders by means

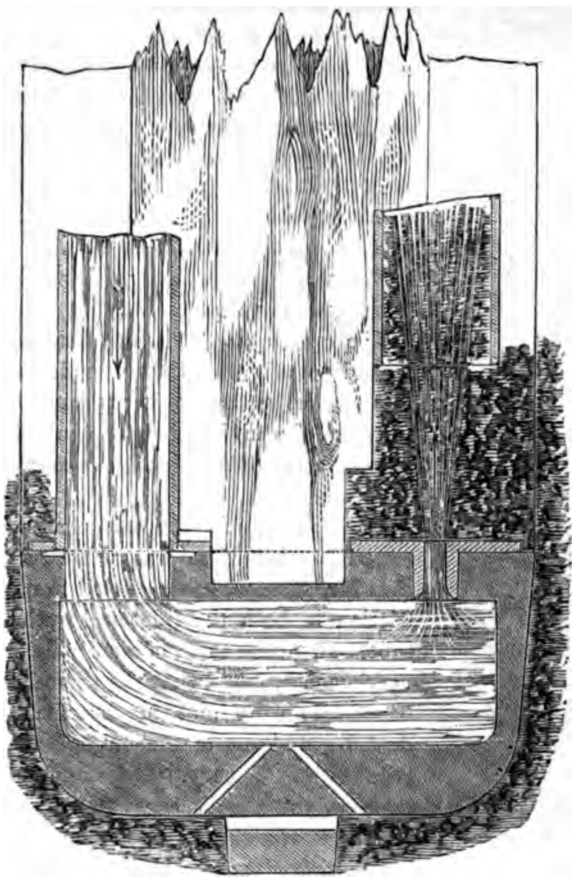


Fig. 1.

of a current of water forced down a pipe into a jet box wedge-shaped, so as to press into the sand, thence through an orifice on the top of the box, having a sectional area of about a fourth of the down pipe. The force with which the water issues from the orifice carries it into an upthrow pipe, the end of which is removed some

distance from the orifice, and with it the sand in which the jet box is embedded.

The two pipes are fixed vertically on a timber frame, the jet box forming its lowest extremity, a space being left open above the same for the admission of the sand; the other extremity of the frame reaches to the top of the cylinders.

Fig. 2.

This mode of sinking has been very successful, although still, to a certain extent, experimental; groups of three 9-feet cylinders, requiring the removal, for each group, of 194 superficial feet of area, having been sunk by it at the rate of $3\frac{1}{3}$ feet per hour, involving the removal of *at least* 24 cubic yards of sand to accomplish this.

The accompanying sketch shews the action of the jet very clearly.

The open space, by which the sand is admitted to mix with the water, is adjustable at pleasure, by the moving upwards or downwards of the upthrow pipe to suit the varying character of the sand to be excavated.

Mr. Jas. R. Napier said that what arrested his attention was the circumstance that Mr. Morton, having tried to reduce the friction in both the inlet and outlet of the tube, by making them of a suitable form and very smooth, found that the smoothness was beneficial on the inlet side, but that the accidental greasiness of the outlet had greatly reduced its efficiency. If he understood the paper aright, the discharge was then no more than with the simple jet without the widening discharge tube. He had seen the conoidal nozzle and widening discharge tube very usefully applied in the city of New York. The town lots were, he believed, rated for water according to their area, and the proprietors thereby became entitled to a certain area of pipe from the main. The citizens, in order, apparently, to make the most of this right, have manufactured conoidal nozzles with widening discharge tubes beautifully polished internally. The small end (inserted in the main)

has the legal area, while from the other a pipe of three or four times the diameter may lead to the premises.

With regard to Mr. Morton's allusions to safety valves, he said that, seeing that a learned society in Glasgow had recently issued a report on the subject, and that he had taken leave, in a letter to the *North British Daily Mail* of 30th November last, to criticise it very unfavourably, he had little new to say, except to state more plainly and in confirmation of Mr. Morton's views, that the effect of thin annular nozzles (which safety valves might be considered to be) on the amount of steam discharged has been entirely ignored in the report, and that such experiments of Mr. R. D. Napier, and others as are available, shew conclusively that the ratio of the area of the tube to its surface greatly affects the amount discharged by a given area.

Mr. Morton then replied. He said that probably Professor Thomson was not aware that the experiments he had referred to were witnessed and verified by many. Although his daily vocation has consisted for many years in making and erecting such apparatus, he was still quite at a loss how to account for the action of the expanding jet within the discharge tube. That such an action takes place is evident, but the *cause* remains to him as great a mystery as ever, and well worthy of further investigation.

XV.—*On an Apparatus for Testing the Lubricating Powers of various Liquids, shewing some hitherto unrecognised facts at variance with the commonly received laws of Friction.* By R. D. NAPIER, Esq.

[Read before the Society, 16th December, 1874.]

WHEN we take into account the immense number of experiments that have been made, and especially the elaborate series conducted by Monsieur Morin at Metz, to ascertain the laws which govern friction under nearly every conceivable circumstance, and when we consider the amount of information derived from those experiments, it might well be expected that any one undertaking to read a paper on the subject would be in a position to give definite rules for the ratio of friction to pressure—at least, for all cases within the range of ordinary experience; but I am sorry to say that, in place of being prepared to state what the laws are, the object of this paper is rather to shew that there are such large exceptions to the generally received law of the uniformity of friction at different velocities, that it becomes questionable whether it is quite entitled to the name of a law at all.

The law referred to is stated to be, that friction is independent of velocity, excepting only that there is what is called the friction of rest, which is always greater than the friction of motion—that is to say, it takes more force to cause one surface to commence to slide on another than to keep it moving; but it takes neither more nor less force to keep it sliding fast than slow. In reply to this I have to observe that the coefficient of friction (that is, the ratio of friction to pressure) frequently increases materially with the velocity, and, on the other hand, often decreases materially as the rate of sliding increases; also, that sometimes the coefficient of rest is not distinguishable from that of motion.

In a note at the foot of page 14 of Rankine *on the Steam Engine*, a formula is given, deduced by Monsieur Bochet of Paris, for the friction of iron skids sliding on rails, which in English feet makes the coefficient of friction nearly equal to $\frac{f}{1 \times \cdot 01 v}$, where f is a

constant ranging between ·2 and ·3, but it is not said under what circumstances it is the one or the other. By this rule the friction at the velocity of 100 feet per second would be about half of that at 1 foot per second, which may be said to be not a very remarkable variation, but nevertheless it is sufficient to shew that at all events in some cases there is a variation due to the difference of velocity; and I think I shall be able to prove that the exceptions to the rule of non-variation of friction with velocity are very numerous.

By means of the machine referred to in the title of this paper, which is constructed for testing the lubricating qualities of different oils, I shall presently be able to shew an example of each of the two opposite effects—that is, of friction, in the first place, increasing materially with the velocity, and *vice versâ;* and in the second place, of friction decreasing materially as the velocity is increased, and *vice versâ;* but according to no law that I have been able to discover, unless we can dignify with the name of a law the fact (if it should prove to be universal, which, as far as my experience goes, may be the case) that with mineral oils the coefficient of friction is less at higher than at lower velocities, and that with animal and vegetable oils the reverse is the case; it is by using one or other of these classes of oils that I hope presently to give experimental evidence of the truth of my assertions; but meantime I shall proceed with my remarks.

For many years I have had, in the way of business, to devote a considerable amount of attention to the construction and use of machinery, which has had to be either driven or controlled by friction; and I have frequently observed results which could only be accounted for on the supposition that in some cases friction varied directly, and others inversely, with the velocity—always understanding the word velocity to mean the *relative velocity* of the two surfaces, or the rate of sliding, and by friction the ratio of friction to pressure, and not the measure of friction expressed in terms of the work absorbed by it, which, of course, increases directly as the speed when the load and coefficient are constant. In other cases it has been evident that the friction was greatest at a certain velocity, and decreased with either greater or less velocities.

The following is an example of the first case at slow velocities:—

A weight of about 10 tons being suspended from a pair of blocks, from which the chain led to a barrel 14 inches diameter, with a brake wheel 42 inches diameter attached. There were five parts of chain in the blocks, so the strain on the chain was about 2 tons. The brake was of the differential kind, proportioned so as to be

self-holding, with a given coefficient of friction, and the state of lubrication at the time I refer to was such that it required a weight on the brake handle to prevent the load from descending. Now, if the coefficient of friction were not affected by velocity, any weight on the lever that is sufficient to *reduce* any acquired velocity of descent must ultimately stop it, and the less the friction the more pressure it must require on the brake lever to counteract the weight of the load.

Well, in the case referred to (and it was one of the greatest difficulties I experienced in satisfactorily using differential friction brakes, and therefore was not at all an uncommon case), the weight on the brake lever was sufficient to rapidly reduce the velocity of slipping from 60 or 70 feet per second to that of a few feet per minute (accomplished in a small fraction of a second), and yet it would go on slipping for an indefinite time at the slower velocity. I then add more and more weight to the brake lever, and reduce this constant velocity more and more till the movement of the friction wheel is quite imperceptible to the eye; but by drawing a line across the friction band and the rim of the brake wheel, it is found, after the lapse of a few seconds, that the line is not continuous, and in the course of a minute or so that quarter of an inch has been moved; and this rate would remain nearly constant for ten or twelve hours. The process could then be reversed by taking off weights, and thus increasing the velocity of slipping up to perhaps 30 or 40 feet per minute, when a sudden decrease would take place in the friction.

In other states of lubrication—and this was usually when a little water had got on the rubbing surfaces—the brakesman would have perfect control over the lowering of the suspended weight, so long as he did not allow it to acquire a certain maximum rate; but if this rate were exceeded, then the brake seemed to lose all power, so that the weight would run to the bottom, with apparently no resistance from the brake, though pressed into gear with the attendant's full strength; yet at the smaller velocities the brake would be nearly self-holding. The cause of the brake losing its power in these cases could be nothing else than the coefficient of friction rapidly decreasing with the increase of velocity.

I have now to speak of a case in which the friction varies rapidly with the velocity, and shall describe an experiment which it is in the power of many people to try for themselves. It is the friction of a belt slipping on a metal pulley that I refer to, or rather the converse of this, which is much more easily tried—that is to say, the friction

between the belt and the pulley, when the pulley is made to revolve while the belt is stationary.

Diagram 1 will explain my arrangement for trying this experiment; and simple though it seems, there is one element in it that makes it difficult to give accurate results, especially at high speeds: this is the great variation in friction caused, as far as I have been

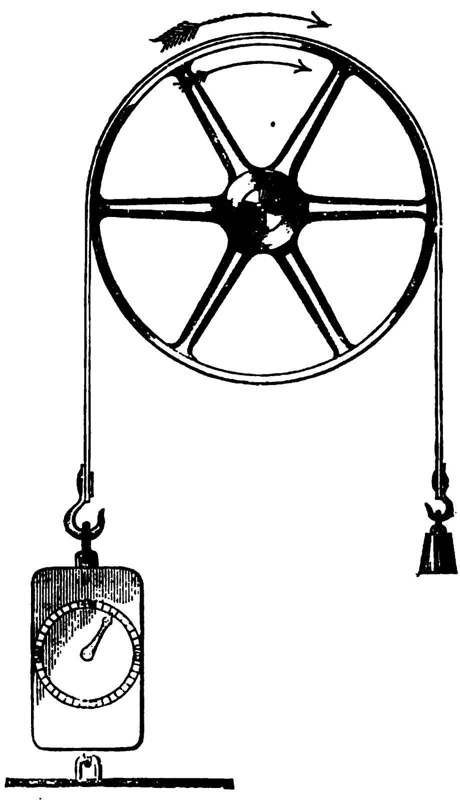


Fig. 1.

able to discover, by slight variations in temperature, the friction increasing rapidly with the duration of the experiment, and apparently arising from the heat caused by the friction, as there was no other cause that was discoverable; but whatever the cause, the effect was to make it very difficult to get correct results; and were it not for the extreme difference between the large amount of friction at high speeds as compared with that at low speeds, I should not have introduced the case here.

A belt about 5 feet long, $7\frac{1}{2}$ inches wide, and about $\frac{1}{4}$ inch thick, single ply, and to each end of which was attached a hook, was placed over an ordinary smooth and turned cast-iron pulley 18 inches diameter. To the one hook was attached a chain, and to the lower end of the chain a spring-balance capable of weighing 200 lbs.; and to the other hook a piece of twine was attached for suspending definite weights from. The weight of the belt and pair of hooks was $6\frac{1}{2}$ lbs., giving about 3 lbs. for the weight of each hook, plus the part of the belt below the axle.

The weight of the chain to which the spring-balance was attached was 17 lbs., and of the spring-balance itself 11 lbs., so that the total strain on the spring-balance end of the strap was 3 lbs. + 17 lbs. + 11 lbs. = 31 lbs. plus the strain indicated by the spring-balance, and on the other end 3 lbs. plus the weight suspended from the hook. If we call this latter strain S_1 and the former S_2, then if the pulley be made to revolve from the spring-balance or S_2 end to the other, and if we ascertain the ratio of the strain S_2 to the strain S_1, we shall obtain the coefficient of friction by the following rule, applicable to the case of a flexible strap half round a pulley:—$C = \cdot 733 \log. \frac{S_2}{S_1}$, where C is the coefficient of friction or ratio of friction to pressure.

In a long article on "Friction" in Spon's *Dictionary of Engineering*, in which are given the results of a great many of Morin's experiments, there is given at page 1,574 a table of his experiments on the friction between leather and cast iron. This table is preceded by the remark, that "though leather is a soft and very compressible substance, its friction is proportional to the pressure and independent of velocity throughout the whole range of the experiments in the next table;" and in that table the friction of leather on cast iron without any unguent, is given as ranging between ·58 and ·55 of the pressure, the average being given at ·563, which is very much higher than the coefficient given for any other condition of lubrication. By the rule given above, which transposed makes $1 \cdot 365\ C = \log. \frac{S_2}{S_1}$, we get with the above coefficient $S_2 = 5 \cdot 87$ times S_1.

On one occasion with $S_1 = 12$ lbs., and the pulley making about 110 revolutions per minute, or about $8\frac{1}{2}$ feet per second, when the pulley and belt got very slightly warm, S_2 became 230 lbs., and $\frac{S_2}{S_1}$, in place of being about 5·9, was about 19, which corresponds with the

coefficient of friction being equal to ·93. Then for the purpose of getting the coefficient at a slow speed, I stopped the engine, and found that 18 lbs. on the one end pulled back slowly the 12 lbs. on the other, making $\frac{S_2}{S_1} = 1·5$, representing a coefficient of only ·13, or one-seventh of that at the greater velocity.

In order to try what the coefficient would rise to, I attached another hundredweight to the S_2 end in such a manner that it would require to lift this extra load before acting on the spring-balance; and by the time the pulley had got so warm that it was unpleasant, and, in fact, barely possible to hold the hand on—probably 170° or 180° Fahr.—with nothing but the hook, weighing 3 lbs., to represent S_1, the strain on the other end mounted up to over 300 lbs., or over one hundred times S_1; which represents a coefficient of nearly one and a half times the pressure. On stopping the engine at this time, I found that 12 lbs. pulled the belt slowly over the pulley, with the strain on the other end just the weight of the hook, or $\frac{S_2}{S_1} = 4$, which represents a coefficient of ·51, being about one-third of that at the fast speed, so that the relative difference was only about half as much in this case as the other.

I have been told that these are experiments on adhesion, and not on friction; but where does adhesion begin and friction end? If the friction were very great at slow velocities I could see some force in the remark.

The belt was new and clean, excepting that the friction drew a small quantity of fatty matter from it, and gave it the oily black appearance of a belt that has been used some time; but when the friction was greatest there was no appearance about the belt or pulley to indicate that the friction would be more than usual.

I now come to the last and, in a practical point of view, the most important part of my subject, which relates to the effect of different lubricants where metals are rubbing on metals.

About eighteen months ago it was of great importance to me to get some information, which I could not get from any books I knew about, as to the friction of various metals when several different kinds of lubricants were used—more particularly, I wished to know the relative coefficients of friction when paraffin or kerosene oil, mineral lubricating oil, and water were used respectively.

The plan that occurred to me of experimenting on the subject will be understood by reference to diagram 2. A pulley A being

fixed on a mandril is put into a lathe, as if to be turned, and is driven at any desired speed; on the upper side of this pulley is placed a half bush B, which is fixed in a frame or bar C. At equal distances from the centre of the pulley are suspended equal weights from this frame. At one end of C and above it is placed a spring-balance. When the pulley is made to revolve, the half bush and frame have a tendency to revolve with it by an amount proportional to the total friction, and this tendency is resisted and

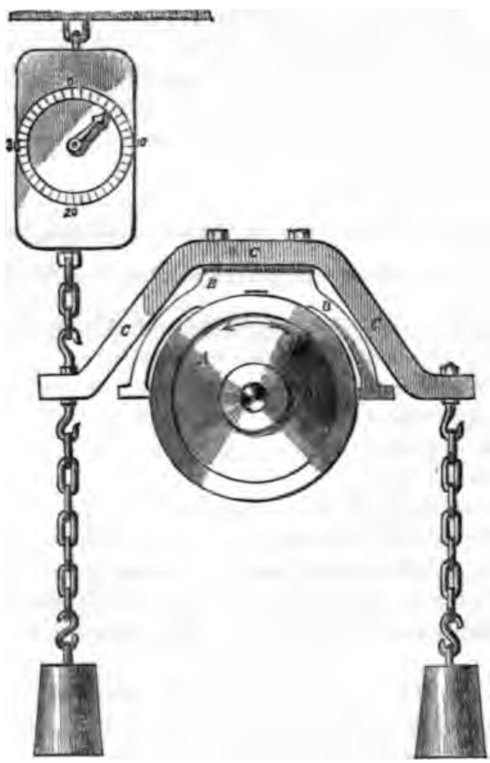


Fig. 2.

measured by the spring-balance. If W represent the weight of the two suspended weights plus that of the half bush and frame, and p represents the pressure on the spring-balance, then the total weight pressing on the friction pulley is $W - p$, and the absolute friction is p multiplied by the distance from the centre of the friction wheel to the point where the spring-balance is attached, and divided by the radius of the wheel. If R_1 equal the radius of

the friction wheel and R_2 equal the distance from the centre of the friction wheel to the point where the spring-balance is attached, then the coefficient of friction $C = \frac{p}{W - p} \times \frac{R_2}{R_1}$.

By this arrangement it will be seen that the coefficient of friction can be ascertained at any instant.

In order to know more definitely the intensity of pressure on the rubbing surfaces, I preferred to reduce them to a small portion of the upper part of the bush, leaving at the same time a small part at each end of the bush, where it is nearly level with the centre of the wheel, to act as guides.

My experiments were made with two sizes of friction wheels: No. 1 size was $2\frac{1}{2}$ inches diameter and 2 inches wide, with 2 square inches of bearing surface; that is, two strips, each $\frac{1}{2}$ inch wide, and the length equal to the breadth of the wheel, the open part between the two strips giving an efficient means of lubricating the whole surface equally. No. 2 size was $7\frac{1}{2}$ inches diameter and $1\frac{1}{4}$ inch wide, the total bearing surface being reduced to 5 square inches.

Generally the weights suspended from the ends of the frame bar were $55\frac{1}{2}$ lbs. each, but sometimes I used more, and, as already explained, the coefficient of friction was ascertained by deducting the pressure indicated by the spring-balance from the sum of the downward pressures, dividing the former by the latter, and multiplying by $\frac{R_2}{R_1}$.

The wheels and bushes were made of various metals, and the velocities were regulated by the various speeds of the lathe.

The arrangement seemed so simple that I quite expected to get all the information I required in the course of a few days' experimenting; but besides the fact that every pair of metals seemed to have its own laws as to the effect of velocity on friction, or rather seemed to have a law of its own for every different lubricant, there were so many differences under apparently similar circumstances that, till a better investigation is made and something like law arrived at, I would feel inclined to substitute the word vagaries for the word laws, when speaking of what governs friction, though, as already intimated, there is one law to which I have not yet found an exception—viz., that with mineral oils the friction is less, and sometimes very much less at high velocities, than at low velocities; but sometimes the variation was mostly at low velocities, and sometimes comparatively little at low velocities.

The following are a few of the more regular results—the average

intensity of pressure being about 60 lbs. per square inch with No. 1 size of wheel:—

Brass wheel and brass bush lubricated with a stream of fresh water.

Revolutions per min. 250, velocity per min. 160 feet, C = ·106
,, ,, 36, ,, ,, 24 ,, C = ·121
Just slipping, ... C = ·129

The same with a constant supply of mineral lubricating oil.

Revolutions per min. 250, velocity per min. 160 feet, C = ·051
,, ,, 36, ,, ,, 24 ,, C = ·129
,, ,, 18, ,, ,, 12 ,, C = ·183
Just slipping, ... C = ·265

NOTE.—Just slipping does not refer to the coefficient of rest, but to moving the wheel slowly by hand.

Wrought-iron wheel and gun-metal bush, lubricant mineral lubricating oil.

Revolutions per min. 250, velocity per min. 160 feet, C = ·10
,, ,, 36, ,, ,, 24 ,, C = ·124
Just slipping, ... C = ·141

The same lubricated with paraffin oil.

Revolutions per min. 250, velocity per min. 160 feet, C = ·12
,, ,, 36, ,, ,, 24 ,, C = ·132
Just slipping, ... C = ·141

The same lubricated with a stream of fresh water.

From 250 revolutions down to just slipping, the coefficient was ·132 and the friction of rest was just perceptibly higher, giving about ·135.

The same sized wheel of cast iron with gun-metal bush, lubricant a stream of fresh water.

From 250 revolutions down to 36 gave C = ·367
The addition of strong solution of salt reduced C from ·367 to ·210

The same lubricated with paraffin oil.

Revolutions per min. 250, velocity per min. 160 feet, C = ·117
,, ,, 36, ,, ,, 24 ,, C = ·143
,, ,, 18, ,, ,, 12 ,, C = ·143

Just slipping and friction of rest not perceptibly different from 36 revolutions.

The same lubricated with mineral lubricating oil.

Revolutions per min. 250, velocity per min. 160 feet, C = ·078
,, ,, 36, ,, ,, 24 ,, C = ·117
,, ,, 18, ,, ,, 12 ,, C = ·128
Just slipping, ... C = ·143

The next two experiments were made with wheels of No. 2 size, average pressure about 25 lbs. per square inch. Wheel of brass composed of 3 ounces tin to the pound of copper, and the bush of brass composed of 13 ounces zinc to the pound of copper—lubricant a stream of fresh water.

Revolutions per min. 350, velocity per min. 700 feet, C = ·094
" " 50, " " 100 " C = ·143

The friction was more with a large stream of water than with a small.

With regard to the friction when water is used as a lubricant, I have to observe that it is exceedingly difficult if the slightest particle of oil has touched the wheel to entirely get rid of it. I have tried numerous acids and alkalies as well as naphtha, but could not depend on getting rid of the oil in less than ten or twelve hours of constant work, with a stream of water on all the time. This is in some cases an important fact to know; for instance, on one occasion, with a small new paddle-wheel steamer I had not applied any oil to the gunwale bearing, till some weeks after she had been running, because I had found, as I supposed, by experience, that for paddle-wheel bearings, water was as good a lubricant as could be; but I had ignored the little oil put on once a day, which I thought was all washed off in an hour or less. However, in the case I am now referring to, although the journal was as polished as a mirror, I tried the experiment of putting some oil on it, and was more than surprised to find the engine increase at once from 60 to 65 revolutions; and though the journal was very little above the water, and was constantly deluged with water from the paddle, the effect of the oil did not wear off so as perceptibly to affect the speed of the engine in twenty-four hours afterwards, and I do not know how much longer it would have run before requiring oil again, for I gave orders for the journal to be oiled every twenty-four hours afterwards.

Before concluding I shall shew what a very small coefficient of friction may sometimes be obtained from the use of water and oil together.

The next experiment was with a brass pulley and cast-iron half bush, the lubricant being paraffin oil, put on occasionally, when it was found that the friction was considerably less a few minutes after being lubricated than immediately after—by the way another rather unlooked for result—the pressure per square inch about 58 lbs.

Rev. per min.	Vel. per min.	C When newly lubricated.	C A few minutes after lubrication.
240	720 feet	·096	·077
55	165 ..	·160	·134
35	105 ..	·154	·105
Just moving	...	·24	...

The friction of rest was exactly the same as when moving quite slowly.

I have now to refer to one or two experiments by the small machine on the table.

It is constructed for ascertaining the coefficient of friction, in the same manner as that to which diagram 2 refers: but it is so adjusted as to give the coefficient at sight without calculation.

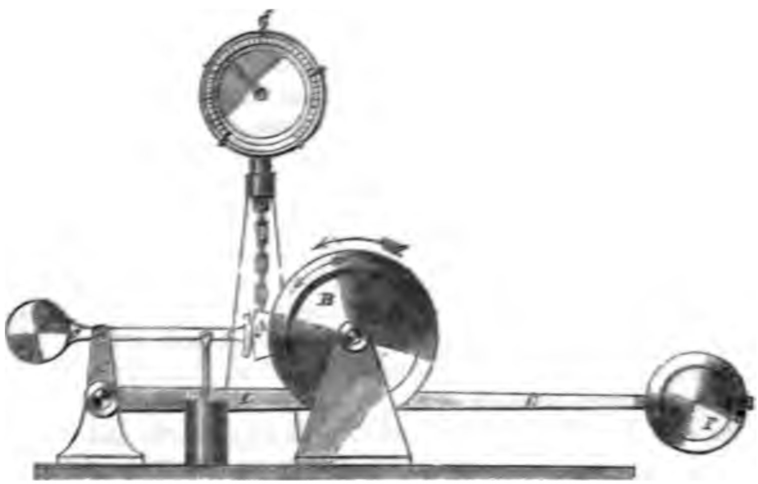


Fig. 3.

Diagram 3 shews the arrangement on an enlarged scale, and I may observe, by way of forestalling criticism on the design, that it was not designed at all, but grew by a process of natural selection as modifications were found necessary.

The small cod piece A is pressed against the friction pulley B by a segment C, which is in fact part of a roller turning on a centre D, mounted on the bell-crank EE, which is loaded by a weight F.

A small chain from a spring-balance G, supports the cod-piece A, which, when the friction wheel is in motion, tends to move along with it. The amount of such tendency is indicated by the spring-balance, which is so proportioned to the weight F, that each division of the balance represents a coefficient of friction ·01 of the pressure.

Allowance is of course made for the chain not being at the surface of the wheel, but a little way outside of it. As arranged, the intensity of pressure is 50 lbs. per square inch, and if more is wanted, it is just to double, treble, &c., the load, and divide the indicated coefficient by two, three, &c.

A belt pulley is attached to the axle of the friction pulley, so that it can be driven by a belt from a lathe at any desired speed.

With olive oil as a lubricant one experiment gave as follows—

Revolutions per min.	1300,	velocity per min.	650 ft.	C = ·1
,, ,,	600,	,, ,,	300 ft.	C = ·06
,, ,,	480,	,, ,,	240 ft.	C = ·045
,, ,,	360,	,, ,,	180 ft.	C = ·035

With paraffin oil the following was obtained—

Revolutions per min.	1300,	velocity per min.	650 ft.	C = ·06
,, ,,	360,	,, ,,	180 ft.	C = ·09
Quite slow,	. . .	. . .	.	C = ·12

With thin mineral lubricating oil—

Revolutions per min.	1300,	velocity per min.	650 ft.	C = ·05
,, ,,	360,	,, ,,	180 ft.	C = ·07
Quite slow,	. . .	. . .	.	C = ·105

At 1300 revolutions a small stream of water running on after olive oil had been used, gave the very low coefficient of ·012, and while the stream of water continued, the addition of olive oil increased the coefficient to ·08, or over six times as much as without it. I had often found in practice the evidence of the fact that a great reduction of friction was caused by a small quantity of water being allowed to run on the top of oil. For instance, in the case of a very short crank pin, I have found that when water was allowed to drop on it, a little oil once in four hours would practically prevent wear; but when the water was stopped, and a large stream of oil was poured on, the brass would begin to grind away perceptibly in a very few minutes, and no amount of oil would prevent it.

Again, I have found brakes which would give complete control for lowering weights when the surfaces were simply oily, but which were perfectly useless when water got on them as well.

One remark in conclusion. If it is found, as my experiments indicate, that with all, or nearly all, mineral oils friction is less at high than at low velocities, and that with vegetable and animal oils the reverse is the case, then I think the point I started with must be conceded, that there is a very large class of cases in which it is

far from correct to say that friction is independent of velocity; but I wish it to be distinctly understood that, as I said at first, the main object of this paper is to shew the necessity for further experiments—to shew, in fact, how ignorant and in the dark we are on the subject, rather than to give light on it. I have tried to give as much light as to make the darkness visible.

Discussion on Mr. R. D. Napier's Paper.

Mr. J. J. Coleman said that the author seemed to confound the *total friction* of the machine with the *coefficient of friction,* and pointed out in what relation these stood to each other. After describing at some length Morin's inclined-plane experiments for determining the coefficient of friction, he affirmed that in such experiments as Mr. Napier's, the heat induced in the parts of the apparatus should not be ignored; and that, further, it was necessary to consider the friction not only of the surfaces in contact, but also that of the particles of the lubricant among each other. From experiments of his own he had found that this friction of the particles was greater in the case of olive oil than in the case of mineral oils, and his opinion was that thick or thin oil should be used according as the pressure between the surfaces was great or small.

Mr. J. P. Smith drew attention to Professor Rankine's saving clause in stating the law of friction—viz., "*provided there be no change of state,*" and thought that in the experiments described a change of state *had* taken place, and that this was the solution of the difficulty.

Mr. Jas. R. Napier was of opinion that the author had decidedly proved his point. As illustrative of a portion of the paper, he mentioned that in the launching of ships the ways generally received a coating of hard tallow, followed by a layer of black soap. The small angle at which many of them were launched (*e.g.*, 1 in 24) might be considered another instance of the efficiency of water and oil as a lubricant; the black soap being chiefly water. He further stated that for heavy machinery the best lubricant he found was castor oil, and for a small foot turning lathe paraffin oil was of little use.

Mr. J. J. Coleman explained that the whole tenor of his argument

was to prove that Professor Rankine's statements remained valid, notwithstanding the experiments of Mr. Napier, who, he reaffirmed, had ignored the fact that in the working of the machine the co-efficient of friction was constantly changing.

Mr. MUIR wished to draw attention to the fact that the author had never for a moment supposed that the coefficient remained the same, his whole object, indeed, having been to shew that it *was* constantly changing. He further pointed out that the particular experiments of Morin which had been described, had no connection whatever with the matter in hand, for the author had been investigating the coefficient of *kinetic* not of *static* friction.

Mr. JAMIESON confirmed from experience Mr. Jas. R. Napier's statement with regard to castor oil as a lubricant, provided it were the real not the so-called castor oil.

Mr. DRON also bore evidence from experience on this point.

Mr. R. D. NAPIER, in reply, referred particularly to the remarks which had been made in reference to the generation of heat in the working of his machine, shewing that the manner of conducting the experiments—viz., driving the machine at low and high rates alternately, would have detected this as a disturbing agent had it really existed.

NOTE.—At the conclusion of his paper Mr Napier exhibited the working of his oil-tester by hand power, in which case there is no arrangement for determining the actual velocity; but, the wheel being lubricated with olive oil, when it was driven at a slow speed the indicated coefficient of friction was from ·05 to ·06; and when driven at a rapid rate the coefficient rose to ·15, and immediately fell again on the speed being reduced. After the above had been frequently repeated, mineral oil was substituted for the olive, when, at a slow speed, the indicator shewed that the coefficient of friction was about ·10, which fell to about ·05 when the speed was increased, and immediately rose again on diminishing the speed.

Experiments were also made shewing the smallness of friction when water is used after oil.

XVI.—*On the Action between the Loch Katrine Water supplied to Glasgow and Various Metals.* By James R. Napier, F.R.S.

[Read before the Society, December 16, 1874.]

The success of a scheme for the economical cooking of food, which I described in a paper to this Society last Session, depended, besides on the arrangement of the parts, on the purity of the hot water which the boiler attached to it could produce. In a second paper the effects of Loch Katrine water, as delivered in Glasgow, on the galvanised iron boiler I had made for it was described—the zinc dissolved off rapidly—the water, hot or cold, came out of a milky appearance, and could only be used for few purposes. It is with reference to some more failures and experiments in connection with the construction of a new boiler—the one now in use—that the following communication is made; for, in passing, the galvanised iron one rusted through and was useless within two months. A cheap boiler was of course a desideratum. The cheapest I could get, which would deliver the hot water pure was what I wanted. I had the choice of various metals and alloys, such as copper, tin, brass, or iron coated with these and other metals.

I selected copper, but hesitated as to its being tinned. The coppersmith, however, settled the point for me so far, by tinning the sheets inside without consulting me, and had the boiler partially made before I became aware of what he had done. Before completing it, however, and perhaps having the expense of another failure, I tested some of the tinned sheets by leaving them for some days in a bath of cold water, and observing the appearance of the water which flowed off when collected in a glass vessel. The result was so very unsatisfactory, that after about a month's similar testing of various other metals and coatings of metals, I had to turn the boiler tinned side out, so as to expose the plain copper to the water; and such is the boiler I have now had in use for more than six months, giving to all appearance pure water. The tinned copper sheets when in the water bath became spotted, the

tin then blackened, and the water flowed off the surface quite of a milky appearance.

I was led unwillingly to make these and more extensive experiments by observing a slight efflorescence, as it were, on the side of a small piece of copper tube which had been immersed for a few days in water, to see if there was any action or apparent alteration in the water, the efflorescence being on a part of the tube which happened to be coated with a little tinsmith's solder.

The results of the action of various metals immersed in Glasgow Loch Katrine water are given below. They are merely those connected with the *colour* of the water, although chemical tests were occasionally applied, detecting the presence of lead and tin, and sometimes copper.

1. Cuttings of sheet copper, exposed for about three months in water—the water apparently pure—the copper tarnished.
2. A partially tinned copper tube, shewing the decay of the tin coating and its redeposit on an exposed part of the copper. The water at first became quite milky.
3. Shews the efflorescence, referred to above, on various parts of a sheet of tinned copper which has been about three and a-half months in the same water.
4. Water after remaining about a week in a tinned copper saucepan. Quite milky.
5. Granulated lead which, after being about six months exposed in water, frequently changed, had not ceased to be acted upon by the water, which still gets milky.

I had for some time been aware of the fact that tinned iron vessels lasted but a very short time in contact with water: it appeared to me that whatever the cause was, they lasted a much shorter time now than they used to do years ago. I ascribed the undurability to the electric position of the two metals, and inferred that the authors of modern works on electricity and magnetism, such as Mr. Fleeming-Jenkin, were wrong in the position they give to iron and tin; for if tin were electro-positive to iron, as they state, it occurred to me that the iron would be preserved by it, just as it is so effectually by zinc. The result of experiments on Sir William Thomson's galvanometer, however, shewed that in all the specimens tried, malleable iron was not negative but positive to tin. Therefore, if the cause of zinc protecting iron from rusting was due to the electro-positive relation of the zinc, then it might be said that the iron protected the tin, instead of the reverse, as is intended, and that probably partially or badly tinned iron rusts

faster into holes than plain untinned iron would do. The numerous experiments I was kindly permitted to make at our University with Sir William Thomson's reflecting galvanometer, on various metals in contact with Loch Katrine water, I need not describe, as they are probably not new. They were made partly from curiosity, to try to discover the relative protecting powers of different metals when in contact in water, on the theory that the positive metal would protect the negative one by itself decaying—the galvanometer being so graduated as to give at once the relative amount of the deviating or protecting force. The chief object I had, however, was, if possible, to find a coating for iron which would be positive to it, and of itself have little effect on pure water. Brass, an alloy or compound of zinc and copper, I found, in former experiments, had apparently as little effect on pure water as pure copper had, although zinc of itself dissolves so readily in it.

I thought it probable that a similar result might happen with an alloy of zinc and tin, and tried Sn 6 Zn, said to have the lowest temperature of fusion. Whether on this account it be a true alloy, or merely a mixture, the result was satisfactory. It is positive to iron, and it may be slightly soluble in pure water, although I could not perceive it in the colour of the water—it might therefore find some uses. I had two iron cooking pots coated, as in the galvanising process, with the tin and zinc alloy. They have been tested by twenty-four hours' immersion in water, and shew some slight rust spots; but seeing that galvanisers find it more economical to waste their zinc, by keeping it so hot that it evaporates visibly, rather than that their goods should have a thicker coating of zinc, put on at a lower temperature without the visible evaporation, I have concluded that the coating on the pots is not the alloy tested at the electrometer, but is a mixture containing less zinc. Mr. Lewis D. B. Gordon informs me that such a coating for iron is not unknown in Germany, and that it is described in one of Dr. Karl Karmarsch's technological works. In this country, I learn that we put a little copper among the tin to brighten it. If the experiments I have referred to have any bearing on the subject, the copper must make the tinned article less durable. I have heard of a milk dealer who put a strip of zinc round the bottom of his tinned iron milk-cans to prevent their rusting through. The dissolved zinc, however, would not likely add any useful property to the milk.

DISCUSSION ON MR. JAMES R. NAPIER'S PAPER.

Mr. MAYER thought that perhaps the author had omitted to notice that in the tin used for galvanising there was frequently a quantity of lead.

Mr. JAMIESON was curious to know if the effects described were peculiar to Loch Katrine water, and described the milky appearance observed in the galvanised water-tanks of a vessel in which he had made a voyage from the Clyde in the summer, adding, however, that the phenomenon did not reappear after the tanks had been filled and emptied two or three times.

Mr. BROMHEAD had found that zinc, *if good*, altered very little although exposed to rain water for years, but that an inferior kind of zinc was in use which deteriorated very much in the same circumstances.

Mr. JAMES THOMSON said that a certain proportion of lime in the water prevented the action referred to.

Mr. MACKINTOSH drew attention to the bright surface maintained by the zinc roofs in Canada.

Mr. SMITH said that his experience went to shew that if the roofing plates were of lead they suffered little harm.

Mr. WHITELAW thought that the effects were purely due to galvanic action, and were much stronger when zinc was in contact with iron.

Mr. HONEYMAN considered that the results which the author had brought before them could not but have something to do with the health of the city.

Mr. COLEMAN said that the decomposed material was perfectly harmless so long as it remained undissolved in the water.

Dr. FERGUS had paid some attention to lead-poisoning, having seen numerous cases of it in London and elsewhere, and he could affirm with certainty that in Glasgow lead-poisoning was of extremely

rare occurrence. He only remembered *one* case in his experience, and it had originated from a totally different cause. Such was also the experience of Professor Gairdner.

Mr. James R. Napier stated in reply that the zinc used was the commercial article; that although pure zinc was said not to be acted upon by pure water, his experiments had reference solely to the action of *Loch Katrine water as supplied to Glasgow* on the ordinary zinc used in coating galvanised iron goods. The water of Kelly Burn at Wemyss Bay, however, has a similar action on the zinc. He had seen the tinned iron roofs of Canada in 1847, and did not know the cause of the iron being so durable there and so subject to decay here, unless it was the dryness of the climate there, and perhaps they were what is called terne or leaded plates, in which case the coating, being according to the experiments he had tried, positive to iron, would protect it. He believed that water with lime in it would prevent its acting on metals, as the Loch Katrine water supplied to Glasgow does. The action of lime in water has been long known to the Sheffield cutlers to preserve iron immersed in it from rusting, and Mr. Young of Kelly has shewn that any alkali has the same effect, but such an application of lime was inadmissible for his domestic boiler. It was cheaper to make a copper one, which gave sufficiently pure water without any trouble.

XVII.—*On the Immediate Results of the Operations of the Glasgow Improvement Trust at last May Term, as regards the Inhabitants Displaced, with Remarks on the Question of Preventing the Recurrence of the Evils which the Trust seeks to Remedy.* By JAMES B. RUSSELL, M.D., Medical Officer of Health, Glasgow.

[Read before the Sanitary Section of the Society, December 14, 1874.]

THE results which the Glasgow City Improvement Trust desires to attain by its proceedings are clearly set forth in the Preamble of the Act by which that Trust was constituted, in these terms:—

"*Whereas various portions of the City of Glasgow are so built, and the buildings thereon are so densely inhabited as to be highly injurious to the moral and physical welfare of the inhabitants,* and many of the thoroughfares are narrow, circuitous, and inconvenient, and it would be of public and local advantage if various houses and buildings were taken down, and those portions of the said City reconstituted, and new streets were constructed in and through various parts of said City," &c.

The first part of this preamble is that with which this paper is chiefly concerned. The Trust obtained power to turn out the inhabitants of certain buildings, with the intention of improving their "moral and physical welfare," in so far as it was injured by those buildings or houses. No one will expect a simple transference from one house to another to produce an effect which can be fully estimated, whether it be good or bad, at the very time of the transference. Moral and physical injury grows into the moral and physical constitution of the individual in the course of his life, and is cumulative in the constitution of successive generations of his descendants. A gutter-child from the Bridgegate is a very complicated production. More forces have contributed to the pitiable result than those which have operated within the short span of his own life, or even passed into his body from the parents who begot him. The evil which the

Improvement Trust sets itself to remedy was worked in successive generations, and the good which it desires to effect cannot be exhausted in a period short of the life of one generation, if not of several.

I make those prefatory remarks, and wish in the title of my paper to emphasize the adjective "immediate," in order to indicate the only part of the "results" of the proceedings of the Improvement Trust regarding which I intend to contribute a little precise information, and in order to prevent you from estimating the value and scope of my paper, either in excess or in defect of its real importance. What I mean by "immediate results" is nothing vague or speculative, nothing sensational or sentimental, but simply such exact facts as are capable of numerical statement—viz., the size, monthly rental, number of inmates per house, distance of the house from the centre of the city, and manner of the excrement disposal of the inhabitants, before the proceedings of the Improvement Trust at last May Term and after.

Since 1870 the Improvement Trust has, from time to time, demolished the houses of some 15,425 persons. At last May Term some 351 houses were pulled down. The districts operated upon were St. Andrew's Square, Calton, and Main Street, Gorbals. Although 351 families were thus expelled, I propose, partly from necessity and partly from choice, for the sake of purity of result, to confine my data, as to size, rent, and inmates, to 243 houses. The remaining 108 are accounted for thus:—In many cases we failed to trace the subsequent residences from not catching the families before they removed. In other cases, from the combination of dwelling-houses with shops, the rental and general character of the occupancy were such as to remove them from the category to which the great majority of the houses belonged; while in the case of a large new tenement in Great Hamilton Street, which was involved in the operations necessary for the formation of a new street, the houses were really of a superior kind, and would not have been interfered with but for this accident of position. A similar remark applies to some of the houses in St. Andrew's Square. Having excluded those houses, the remaining 243 are on the whole fair samples of the utterly insanitary house, and their 990 inhabitants fair specimens of the miserable population whose "moral and physical welfare" are alleged in the Preamble of the Improvement Act to be injured by the houses which they inhabited.

The three areas operated upon present some differences, more

particularly as to the rental of the houses demolished, which is highest in the Central District, lowest in the Southern District, and intermediate in the Eastern District. Still, the facts regarding these demolitions may best be considered in the aggregate.

1st. *Size of House.*—*Before* the operations, of the 243 families whose subsequent history has been traced, 118 lived in houses of one apartment, 96 in houses of two apartments, 23 in houses of three apartments, and 6 in houses of four apartments. *After* the operations those 243 families were housed as follows—viz., 96 in houses of one apartment, 116 in houses of two apartments, 16 in houses of three apartments, and 3 in houses of four apartments; this accounts for 231 families. The remaining 12 were distributed thus:—5 to the suburbs, 2 to the country, 3 to lodgings, and 2 to Ireland. For the sake of comparison these whole numbers may be reduced to percentages, when we find that *before* the intervention of the Improvement Trust 48½ per cent. of the families lived in houses of one apartment, *after* 39½ per cent.; that *before* 39½ per cent. of the families lived in houses of two apartments, *after* 48½ per cent.; that *before* 9½ per cent. lived in houses of three apartments, *after* 6½ per cent.; that *before* 2½ per cent. lived in houses of four apartments, *after* 1 per cent.; leaving 5 per cent. who *after* these operations settled in the suburbs, in lodgings, or removed to the country districts of Scotland or to Ireland. The same facts may be stated in another way, thus:—Of 118 families living in houses of one apartment, when expelled by the Improvement Trust, 76 removed to houses of the same size, 39 to larger houses, 2 to lodgings, and 1 to the country in Scotland; of 96 families living in houses of two apartments, 66 removed to houses of the same size, 10 to larger houses, 17 to smaller houses, 1 to the country, and 2 to Ireland; of 23 families living in houses of three apartments, 4 removed to houses of the same size, 18 to smaller houses, and 1 to lodgings; of 6 families living in houses of four apartments all removed to smaller houses.

2nd. *Rental of House.*—The monthly rental was ascertained in each case, both of the house which was left and the house to be occupied. The average rental, according to the number of apartments, has been calculated in both cases. It is evident that some differences existed in the value of the property demolished in the different districts of the city. It seems to have been lowest in the Gorbals, and highest in St. Andrew's Square area; thus in Gorbals,

the average monthly rental of one apartment in the property demolished was 6s. 3¼d.; in Calton, 6s. 7½d.; and in St. Andrew's Square, 8s. 7½d. In Gorbals, the average monthly rental of two apartments was 8s. 10¼d.; in Calton, 10s. 1½d.; and in St. Andrew's Square, 10s. 3½d. Throwing all these districts together, and calculating the average rental paid for each size of house by the families ejected, in the houses abandoned, and in the houses into which they removed, we find it stands thus:—In the *old* buildings, a house of one apartment cost on an average 6s. 7¾d. per month; in the *new*, 7s. 11½d. per month. In the *old* buildings, a house of two apartments cost on an average 9s. 7¼d. per month; in the *new*, 11s. 6¼d. In the *old* buildings, a house of three apartments cost 11s. 5¾d. per month; in the *new*, 18s. 1½d. In the *old* buildings, a house of four apartments cost 13s. 4¼d. per month; in the *new*, 17s. 2d. In all cases, therefore, the operations of the Improvement Trust brought an increased expenditure in the shape of rental to the families involved. Stated as a percentage upon their former rent, this increase amounted to 20 per cent. on the rental of a house of one apartment, to 20 per cent. on a house of two apartments, to 58 per cent. on a house of three apartments, and to 28 per cent. on a house of four apartments.

I must pause here to make a few remarks on these comparisons between the sizes and rental of the houses demolished, and the houses into which the families occupying them removed. The number of apartments in the houses demolished is for the most part an entirely delusive method of estimating the accommodation afforded, whether calculated according to the cubic space of those apartments or as to the sufficiency of the structure; but especially as to the cubic space. To speak of three or four apartments in the old houses is generally a mere fiction, and a fiction of a very tragic kind. Thus, what could a house of one apartment be at 2s. 6d. or 3s. 6d. per month, or a house of two apartments at 5s. per month, or a house of three apartments at 5s. 10d. per month, or a house of four apartments at 7s. 10d. or 8s. 6d. per month? Yet these are all actual quotations of rents paid for such houses in the property lately demolished. It is therefore evident that a very great part of the contrast between the average rental of the old and new houses, especially of those of three and four apartments, arises from the fictitious nature of the accommodation afforded by the old houses. The case of a tenant paying more rent in those circumstances is precisely that of one who ceases to buy a cheap but bad and adulterated article, and buys instead a more expensive but good and pure article.

3rd. *Number of Inmates in House.*—Overcrowding of individuals in the family is more serious than overcrowding of families on the soil; hence it is important to ascertain whether the number of inmates per house was greater before or after the operations as regards the families involved. This is all the more important owing to the great increase in house rent, which we have just seen was an immediate result of the change to the families displaced. I find, then, that in the *old* houses of one apartment the average number of inmates was 3·6, and in the *new* houses of one apartment 3·3; in the *old* houses of two apartments the average number of inmates was 4·6, in the *new* houses of two apartments also 4·6; in the *old* houses of three apartments 4·3, in the *new* houses of three apartments 4·9; in the *old* houses of four apartments 3·6, and in the *new* houses of four apartments 6·3. Still further reducing the comparison to the number of inmates per apartment in the old and new houses, I find that in the *old* houses 990 individuals were accommodated in 403 apartments, giving an average of 2·4 inmates for each apartment, and that in the *new* houses 949 individuals were accommodated in 388 apartments, giving still the same average of 2·4 inmates for each apartment. Returning to my remark as to the fictitious nature of the old house accommodation, it is quite certain that the same number of inmates per house or apartment in the old and new houses really means an increased cubic space in the new houses—this is especially true of the houses of three and four apartments. In the old houses these apartments are merely nominal, in the new they are real.

4th. *Distance from the Centre of the City.*—The operations of the Improvement Trust at last May Term were confined to three areas—the Calton, St. Andrew's Square, and Gorbals. The Cross may be taken as the centre of the city, as almost equi-distant from all points of the circumference, and certainly as the nucleus round which the city has grown—the oldest part of it, and the most densely inhabited and most unhealthy. Taking the Cross, therefore, as the centre, I have determined the relative distance, before and after those operations of the Trust, of the houses occupied by 263 families displaced, by marking their position on a map in relation to circles described, with a radius increasing by quarters of a mile in distance from this centre. *In their original habitations*, of these 263 families, 29 were within a quarter of a mile of the Cross, 162 within half a mile, and 72 within three quarters of a mile. *In their new habitations*, 26 were within a quarter of a mile of the Cross, 79 within

half a mile, 108 within three quarters of a mile, 29 within one mile, 13 within one mile and a quarter, 3 within one mile and a half, and 5 beyond the municipal boundaries. Reducing these numbers to percentages of the whole number of families displaced, we get this comparative result: In their original habitations 11 per cent., in their new 10 per cent. were within a quarter of a mile of the Cross; in their original habitations 62 per cent., in their new 30 per cent. were within half a mile of the Cross; in their original 27 per cent., in their new habitations 41 per cent. were within three quarters of a mile of the Cross; in their original, within one mile of the Cross, none; in their new habitations, 11 per cent.; in their original, within one mile and a quarter of the Cross, none; in their new habitations, 5 per cent.; in their original, within one mile and a half of the Cross, none; in their new habitations, 1 per cent.; in their original, beyond the municipal bounds, none; in their new habitations, 2 per cent. The change may be summed up in the statement, that *before* these operations only 27 per cent. of the families displaced lived beyond half a mile from the Cross; but that *afterwards* in their new houses, no less than 60 per cent. found themselves beyond that distance. Or taking a wider circle as the limit, none of the families were over three quarters of a mile from the centre of the city in their original homes, but now 19 per cent. are outside that circle.

5th. The only remaining point in the immediate change in the circumstances of the families evicted which can be exhibited in this form, is *the method of excrement disposal*. Including for this purpose also the total 263 families whose future residence was traced, I find that only 12 of these had water-closet accommodation originally, but 35 have such accommodation in their new houses—that is, whereas only 4½ per cent. of the families whose houses were demolished sent their excreta into the sewers before the demolitions, nearly 13½ per cent. did so afterwards.

This indicates a very decided tendency to increase the proportion of the total excreta of the population which is sent into the sewers, and so to add to the pollution of the Clyde at a rate increasing beyond the mere increase of the population. As to the immediate effects of the change from privies and ashpits, as the method of excrement disposal, upon the families themselves, two things must be taken into consideration: *First*, That from the close occupation of the ground in the old localities, for the most part no site was to be had where a privy or midden could be placed so as not

to be a nuisance, and even a source of injury to the health of the inhabitants. *Second,* That of the 35 families who found themselves supplied with water-closets after these operations, only 13 found them in their houses. The remaining 22 found them on the stair. The change from a midden reeking in a confined court, possibly right under your window, or at the foot of the stair, to a water-closet on a stair well ventilated and cleanly kept, must be admitted to be for the better.

On the whole, then, the result of the intervention of the Improvement Trust, as regards those families, has been at once to cause their redistribution into houses better suited to their requirements as to size, and situated much farther from the centre of the city, to compel them to incur some 20 per cent. more expenditure for rental on one and two apartment houses, and considerably more for houses above that size, and in some cases to improve the method of their excrement disposal.*

I have now placed before you all that seems to me to be involved in the title of my paper; but as a supplement, you will allow me to add a few general remarks on the conditions necessary to ensure the success of the Improvement Act, and particularly on the prevention of the return of the evils it is intended to remove.

When a scientific surgeon has removed a tumor from the human body, his first impulse is to submit it to microscopic examination, and to determine from the results of this examination what is its exact nature, and above all whether it has a tendency to recur. In like manner, no physician worthy of the name is satisfied with simply treating his patient, or even curing the disease. He also inquires into the origin of the disease, observes its habits and characteristics, and if possible gives such advice as will prevent its recurrence. The ailment of which the Improvement Trust desires to relieve us is a very serious one, and the cure of it very costly, and with this, as with our own personal diseases, prevention is not only better but cheaper than cure. I propose, therefore, to glance at the nature, history, and mode of prevention of the civic disease against which the operations of the Improvement Trust are directed.

The disease is overcrowding of various kinds—

1. Overcrowding of tenements on the soil, or over-building.

* I wish to avoid stating mere impressions; but it is quite fair to add that the impressions conveyed to the minds of the large and intelligent sanitary staff, whose daily duties have brought the entire operations of the Trust under observation, as well as to my own, are in harmony with the facts stated concerning that section of the operations which was carried out at last May Term.

2. Overcrowding of dwelling-houses in the tenement, and internal defects of structure.

3. Overcrowding of inhabitants in the dwelling-house, or overcrowding proper.

Each of these three forms of overcrowding is an evil in itself, and may exist independently of the other; but in fact they are cognate, and are generally found together, each intensifying the evil effects of the other, and all together producing that state of chronic ill-health, with acute exacerbations, which is a feature of the life of Glasgow. Let us run rapidly over each form separately, touching on these three points,—the injury which each causes, especially to the "*physical* welfare" of the inhabitants, the natural history of each (which will guide us to the prevention of each), and lastly, how far we have succeeded in adopting the measures necessary for prevention.

1. *Overcrowding of Tenements on the Soil, or Over-building.*

Every stone deposited on the surface of the earth displaces so much air, and therefore every tenement added to a city removes further from its inhabitants the great store of outer atmosphere from which alone the air vitiated by the functions of their lives, and the processes of manufacture, can be renewed. Hence there must be broad passages left for the entrance of air from the open country, and spaces preserved, which not only are reservoirs of fresh air, but the soil of which will provide playgrounds, places for rest or exercise, and sites for ashpits, washing-houses, and other conveniences necessary for comfort and even for health. A study of extant maps of Glasgow throws considerable light on the natural history of this form of overcrowding in old Glasgow. The idea of the city was, central thoroughfares east and west, and north and south. End-on to the building line of these streets we see long narrow strips, extending in what was the natural direction of the growth of a house placed endwise to the street—*backwards*, looking on the maps like sections of geological stratification, with cracks or flaws between. These were the closes or wynds—parallel intervals left between tenements simply for convenience of access, only wide enough to permit two persons to pass, or perhaps a barrow or a cart. Each proprietor was bent on covering every inch of his grounds with his building, and the only function exercised by the Dean of Guild Court was that expressed in the phrase, which is still in use, "to grant a lining"—that is, to see that if he *built up to*, he should

not *build over* the line of his holding. What the result was in process of time has been graphically described by Sir James Watson, and so recently quoted by Bailie Morrison that I need not dwell further on the picture. At the end of last century, in the first extensions of the city in the feuing of Tradeston, Hutchesontown, Laurieston, Cowcaddens, &c., a different principle was adopted, which gave a new direction to this form of overcrowding, although at the same time it increased the number of streets in proportion to the surface occupied. We may call this the hollow-block plan, appearing on the map as the outlines of squares or parallelograms. These were not happy designs for the free circulation of air, but year by year you find black squares planted in the middle of those hollow squares, and long lines budding out from the sides, or running parallel within a short distance of the sides. This was the new development of overcrowding or over-building. Just as a mason erects the solid shell of his wall and then fills up the interval with packing, so the proprietor first built his block like a box, and then packed it with other houses, in many cases placed back to back. Hence those ominous black squares on the Post-Office Map of the present day. The operations of the Improvement Trust are almost entirely confined to the product of the older form of over-building, but they are scarcely less needed in the localities which have been spoiled by this more recent development.

The next question is, How far have we profited by the lessons of the past, and succeeded in preventing the continuance of this over-building? My answer is, Not so much as we ought to have profited and prevented it. When the Trust has finished its work, our streets will be the finest in the world. We are also getting squares and parks and other breathing spaces. We have got entirely rid of the old way of development of buildings parallel to each other, and vertical to the line of the street; but if you look at our Post-Office Map you will find it studded year by year with more of those squares, like the block plan of boxes; and if you go and inspect those squares *in situ*, you find that boxes they are to all intents and purposes, containing stagnant air. If the process of over-building is developed to its next stage, by packing those boxes to any degree with buildings of any kind, whether intended for dwellings or not, then you reproduce to the full the old evils. I admit, of course, that there is no chance of this being done in the present day to the extent to which it has been done in the past; but I think I am quite safe in asserting that the principle that a

building of any kind displaces vital air, and impedes its circulation, is not sufficiently acknowledged in the powers of the Dean of Guild Court for preventing over-building. It is barely worth consideration whether a tenement which darkens my windows and impedes the access of fresh air to my house is a warehouse, or a singing saloon, or a four-storied land of dwelling-houses. But apart altogether from the aggravation of packing those hollow blocks with further erections, I venture to suggest that they are in themselves faulty, and that some other principle of ground plan should be adopted which would permit a free current of air along the back as well as the front of every tenement.

2. *Overcrowding of Dwelling-houses in the Tenement, with Internal Defects of Structure.*

The aggregation of dwellings in the tenement is an essential feature of the Scotch system of flats with common stairs, as contrasted with the English system of self-contained houses with common courts. The attendant evils, to the mitigation of which special attention ought to be paid, are the vertical accumulation of houses by the imposition of successive flats, and the horizontal or lateral accumulation of houses in the flats, involving the removal of the house still farther from the air and light, which possibly are already greatly debarred by over-building; the vitiation of the air with animal excreta which inevitably follows, and the tangible dirt which is always associated with darkness. The Scotch system also necessitates a much greater degree of personal contact and communion than the English. The result of this in a tenement overcrowded with houses, and defective in internal structure to boot, is that the inhabitants actually breathe and swallow each other as well as come into bodily contact. The stairs and lobbies have that curious indescribable sour smell which can be perceived the moment you enter a close in the overbuilt part of our city. This co-operates with internal overcrowding in producing a low state of vitality and that constant irritation and defective discharge of the functions of the lungs which issues in bronchitis and consumption, and makes the city, so to speak, asthmatic. Then consider the circumstances of poor children in such tenements. Raised above the street level to such a height, and separated from such scant and dangerous room for play and exercise as those streets and courts afford, by dark lobbies and steep dark stairs, what can the poor things do? The playground of most of

the children of Glasgow below five years of age is the lobby and the stairhead. It is a sorry thing to hear their voices, and to feel them, for often you cannot see them, running about or sitting in groups in such places. No wonder that they are deformed with rickets and prematurely aged; and as to the mortality which prevails among them, the marvel is that so large a proportion of them ever reach adult years. As for stamping out epidemic diseases, such as scarlet fever, measles, and hooping cough in such circumstances, it is impossible; and it is only by the rigid enforcement of hospital treatment that their parents and the adults who live in these localities can be saved from decimation with typhus—that scourge of overcrowding and dirt.

This then is a broad and hurried sketch of the evils to which the system of flats, especially when accompanied with undue vertical extension and overcrowding of dwelling-houses in the flats, tends. What can we do, and what have we done to reduce them to a minimum? The chief structural defects are in our *common stairs* and our *lobbies*.

The common stair of a Scotch flatted tenement is the analogue of the English court, not only as the means of access to the houses, but especially in old buildings, in respect that it contains the common jaw-box—the representative of the English gully-hole—and the common water-tap for the supply of water; and in modern buildings in respect that it contains the common water-closet, the representative of the privy or trough water-closet which stands at the head of the English court. Yet with all this similarity of function, the English court is at the worst a box open above to the free air, while the Scotch common stair is *at best* a longer, narrower box, fully open only at the lower end, with or without certain mockeries of ventilators at the upper end, and with windows at intervals, which may admit light, but are never opened, and serve no useful purpose for ventilation until by a providential accident, or a merciful exhibition of malice, the panes of glass are smashed. In their *worst* form it is hard to say what the Scotch common stair is, but a dark noisome tunnel buried in the centre of the tenement, and impervious both to light and air, excepting the fetid air which is continuous and undiluted from the house along the lobbies and down to the close, from which you start on your perilous and tedious ascent.

Now, I confess to you, I do not think we have made much progress in recent times in the structure of our common stairs. In the oldest houses the best form probably was the turnpike

standing outside the main wall, like a huge round chimney stalk; the worst was the same turnpike running up through the heart of the tenement; but there were also good broad stairs with roomy landings, having windows in the main wall, and so making ventilation from the outer air possible. The more recent introduction of the hanging stair, in place of the turnpike in the centre of the tenement, ensures a passage of air right up to the roof, instead of only along the length of the stair. This with ventilation at the top is an improvement, but it still falls very far short of what ought to be.

Rather than dwell on those architectural details, of the terminology of which I know little, I shall endeavour to give my notion of the principles which it is the business of the architect to carry out in the structure of a common stair.

1. It should touch the open air at every flat or landing between the flats. I have been told this is impossible in corner tenements, and I know it is seldom done in such situations; but it is just there that the greatest need of ventilation exists, because of the number of dwelling-houses having access to the stair in a corner tenement. I do not believe in impossibilites of this kind, and there is no doubt this condition would be complied with even there, if made compulsory.

2. A common stair should not only touch the open air, but the air should have free access independent of the control of any tenant. Fresh air is as essential as fresh water, and should be brought to each individual door. The individual householders may please themselves on the matter of admitting the fresh air further, but it should not be possible by closing a window to deprive all the neighbours of this necessary of life. In Mr. Carrick's model houses in Drygate, and in a tenement in the Northern District, there is a free space in the main wall at each landing, protected by a railing, while in Dr. Hill's property, recently erected on Garngad Hill, the common stair is a turnpike outside the main wall, and the air blows freely across each landing by an equally perfect arrangement of structure.

3. Such a thing as a common stair which requires to be lighted artificially in the day time, should not exist, and of course would not exist if the previous conditions were fulfilled.

4. The last defect in our common stairs to which I shall allude, is the universal want of proper ventilation at the top of the staircase. This is a most important matter when there are windows and water-closets on the stair — these windows, as already re-

marked, when a harmony of opinion among a dozen house-wives has to be obtained before they are allowed to remain open, being good for nothing as an access for air. There should always be some equivalence between the area of apertures admitting fresh air and those giving egress to foul air. Yet, as a rule, the top of those stairs is hermetically sealed with a glazed skylight, and perhaps there is a hole entering beneath the roof, or an aperture in the skylight about six inches square, or even less.

So much for common stairs. Let us now turn to the lobbies which give access to the stair, and ought to lead the fresh air to the very doors of the dwellings.

If we inquire into the natural history of the lobbies of the buildings within the area of the operations of the Improvement Trust—those T lobbies and L lobbies, and infinite long lobbies, of which you have heard so much—we find that the immense majority of them have arisen in this way, by throwing open the front door of a large house and letting each several apartment to a separate tenant, a process technically known as "sub-dividing" or "making down" a house. You will remember to what use for rhetorical effect Dr. Guthrie puts this practice in his sermon, *The City: its Sins and Sorrows*, when he compares the lower parts of Edinburgh to a submerged forest: "In their economical, educational, moral, and religious aspect, certain parts of this city bear palpable evidence of a corresponding subsidence. Not a single house, nor a block of houses, but whole streets, once from end to end the homes of decency and industry, and wealth, and rank, and piety have been engulfed. A flood of ignorance and misery and sin now breaks and roars above the top of their highest tenements." This is the poetry of facts; but we have at present to deal with the effect of such a change on what was once the lobby of a private house, but what is now the lobby by which access is obtained to six, eight, or more distinct houses occupied by as many families. It is hardly necessary for me to enter into details. Let any one of you imagine what would be the state of matters if your own private residences were suddenly to suffer such a change; then bethink yourselves of the condition of a common stair in the Saltmarket, which gave access in olden times to four or five houses, of say six apartments, but which now accommodates from four-and-twenty to thirty families. If any of you wish to see easily recognisable illustrations of a more modern kind, you will find them in St. Andrew's Square.

Although the immense majority of those lobbies were, as I have said, originated in this way, a few were primarily planned as we

find them; begotten, let us suppose, in the minds of young architects under the evil influence of the examples furnished by the made-down houses.

Now arises the question, Have we profited by the lessons which experience ought to teach us in reference to this practice of "subdividing" or "making down" houses? I am sorry to say not in the least. The plan of a house is the elaboration of an idea, the consistency and general correctness of which, in a sanitary point of view, rests upon the fitness of the design to the mode of occupancy. Disturb this relation in any way and you land at once in a condition which was never anticipated or provided for by the architect. If a man takes a house which was originally designed as a segment or fraction of a house, he is somewhat like one who buys one article of what was to him who possessed the whole a complete suit, and fancies that he is fully clothed. Yet to this day there is no check on this sub-division of houses, and the City Assessor will tell you that year by year, where formerly he had but one tenant on his roll, he finds that there are several. There have been no structural alterations, no authority has been asked from the Dean of Guild Court, no one is consulted in the public interest. A landlord finds that a demand for one or two apartment houses has arisen in the locality where he has three or six apartment houses that will not let. Like his predecessors in the area of the Improvement Trust, he merely throws open the front door and makes down his three or six apartment houses to meet the demand. This is in effect the erection of a new tenement, and a considerable proportion of our smaller-sized houses are produced in this way. If at the end of a lobby running in a straight line from the landing you have two houses of three apartments, and these are made down into single apartment houses, you have at once a T lobby of the worst description. If you have two front doors on a landing, opening into houses of four to six apartments, and these are made down, you will probably have two L lobbies. No matter with what intelligence and care the original plan may have been drawn, and however healthy and unobjectionable the houses may have been, no sooner is the mode of occupancy altered than the whole plan becomes disorganised.

In the present state of the law this process cannot be prevented, and can be remedied only *after the fact* by the certificate of the Medical Officer, that there are in such a tenement lobbies defective in light and ventilation, so as to be a nuisance and injurious to health. This ends in a reference by the sheriff to an architect or

an architect and a doctor, and perhaps in a tedious legal process which may or may not lead to the remedy of an evil which ought never to have been allowed to come into existence. Obviously there ought to be no alteration in the mode of occupancy of a tenement until authority has been obtained from the Dean of Guild Court. The result of such an enactment would be that the alterations requisite to ensure the necessary light and ventilation would be enforced before the change, and before any injury was done to public health. We see daily how far proprietors can look before them in the erection of houses on the street level, which may ultimately be more profitable if let as shops. Any hardship involved in such a rule as I have mentioned would probably be obviated by a similar prevision in the drafting of the original plans. However this may be, I have no doubt that your more modern tenements of working and middle-class houses, built on the box plan, will, if subjected to this process of making down, become in a few years little better than the rookeries which you are now demolishing, and which were produced by the same process.*

As in the case of the common stair, the principal points to be remembered in the construction of a lobby are these :—

1. It ought to lead fresh air to the very doors of the dwellings to which it gives access. The ventilation should be such that no stagnation can be possible, making the air of the lobby and of all the houses opening into it continuous and common. A tenant ought not to be able to send his aerial sewage into his neighbour's house along the lobby any more than to cut off the fresh air by keeping a stair window shut. In the case of long lobbies with many small apartments, or in the case of lobbies with angles and tortuosities, nothing but through-and-through ventilation from the stair at one end to the open air in the main wall at the other will be effective. Yet it is not uncommon to find the lobby door in a house which has been made down still in use and shut at night, producing inside a condition something like that of the Black Hole of Calcutta.

2. Darkness in a lobby is most objectionable—it nearly always means dirt, and can never be consistent with ventilation.

* The abuse in English houses, corresponding to that of "making-down" in Scotch flats, is "sub-letting," which would require to be regulated by special legislation.

3. *Overcrowding of the Inhabitants in the Dwelling-House, or Overcrowding Proper.*

The last of the evils with which the Improvement Trust contends is *overcrowding of the inhabitants* in the house, or overcrowding proper.

Overcrowding of the house has no direct relation to the structure of the tenement, and consequently any effect which the operations of the Trust may have upon it is not so direct as in the case of over-building and overcrowding of houses in tenements. I believe that in and of itself the overcrowding of houses is worse in its moral and physical effects than either of the other forms of overcrowding to which I have alluded. No tenement of flatted houses, however well planned and however surrounded by free space, can be over-populated without becoming a hotbed of disease and (especially if lodgers are the extra inhabitants) of immorality. As to the history of this vice of our cities (for it is, in fact, a vice inherent in a great part of our population, not a necessity of structure or even of circumstances), I believe it came to us with the Irish, or at least attained its fullest development with their advent. There can be no doubt that it is the Irish and the Scoto-Irish who are at this moment the most obstinate overcrowders. There is very little of it among the Lowland Scotch. That worst form of overcrowding—the introduction of lodgers within the family circle—is almost confined to the Irish.

As to the prevention of overcrowding, I believe that it is a vice which will, probably, never be eradicated from a large mass of our population. I mean that, suppose you had every family in a duly proportioned house to-morrow, if you simply let them alone for six months, you would find them living like pigs again. It is a vice closely related to intemperance, both as a cause and as an effect. In 1865, in his Report to the Privy Council on the "Housing of the Poor in Towns," Dr. Hunter said—"From one point of view crowding in Glasgow means the diversion of income from rent to supply whisky." This still holds true of those habitual over-crowders; but I am afraid it must be said that many of our respectable Scotch artisans have a great deal to learn in the distribution of their outlay between house, food, and dress. They fancy every shilling which can be pinched off the rent is a clear saving, while on food and dress they spend freely, if not extravagantly.

Glasgow was the first city to grapple with this evil in the Police

Act of 1862, which gives power to measure the cubic contents of any house consisting of "not more than three apartments," and if the cubic contents are found to be under 2,000 feet, to affix a ticket on the door on which the cubic space and the number of inmates proportioned thereto is stated. All such houses may thereafter be visited at night, and a fine may be imposed for an excess of inmates or overcrowding. These were extraordinary powers; but no one who knows anything of the habits of the people affected by them (who are not the working classes as we see them pouring from our shipbuilding yards and engine works, in short, not the artisan, but the unskilled labourer and the grade still lower, our criminal classes) can have any doubt of their necessity; nor, I am glad to say, can any one who knew Glasgow as it was then, and knows what it is now, have any doubt as to their efficacy and usefulness. Still, if you relaxed your repressive efforts, the old state of matters would return in a few weeks. The transference of those people from the Bridgegate to new tenements, let us say, in Nuneaton Street or Hopehill Road, will not at once divest them of their habits, though possibly by keeping them forcibly during one generation in circumstances of decency and health, new habits may grow up and become stable in their descendants. But we must not be restrained by any squeamishness about ticketing new property, and so giving it an ill name, if we find overcrowding has been transferred with the old tenants of our demolished houses. If a landlord finds that such a process deteriorates the value of his property, then he must prevent the overcrowding, otherwise ticketed it must be.

Only two remarks occur to me with reference to the enforcement of the law against overcrowding, which of course rests with the magistrates.

1. I think no mercy ought to be extended to overcrowding which is caused by the introduction of lodgers into the family, cases which are subjected to heavier penalties when the house has been scheduled as "let in lodgings." There can be nothing more abominable and vicious in its results than this habit of taking strangers, generally young unmarried men, into a house which is already straitened to accommodate its legitimate occupants. Admonitions will not remedy such cases—only fines, which will make the violation of the law a losing game, will put them down.

2. In cases where the overcrowding arises from a family having grown beyond the dimensions of the house, or where only the members proper to the family are found in it, I think there is room for the exercise of a discretion based upon a broad con-

sideration of the entire circumstances of the family, which would be paternal if not exactly judicial. These circumstances are, the income of the family, and whether there is any vicious source of outlay, such as intemperance. Where you find a husband or a wife expending in drink what should go to the additional rent of a larger house, it would be not only just but kind, to compel them to go to a larger house, and so perhaps convert an evil into a good. Also where members of the family are working as well as the parents, a large sum of money is frequently coming in, while the inmates are living in a way which is not only injurious to health but indecent. Again, it is not uncommon to have daughters bringing husbands into a crowded house, and sons bringing wives, a violation of all decorum, at best a false economy, and very often associated with improvidence, if not intemperance. In all cases even of family overcrowding, a dirty house should be visited with a penalty. Dirt intensifies the dangers of overcrowding, and is an indication of the social degeneration to which it tends. By the introduction of such considerations as those, the legislation against overcrowding might be made a powerful lever for the elevation of the population to a higher ideal of the domestic life, and to habits of self-denial, for the purpose of maintaining that ideal.

In conclusion, the operations of the Improvement Trust must in themselves be productive of good, inasmuch as they expel, from circumstances than which none worse could be found or imagined, a body of morally debased and physically deteriorated inhabitants, and make straight and spacious thoroughfares, in place of cramped and inconvenient wynds and closes. But, as in war, a body of troops may be well equipped and act effectively and successfully against the enemy, and yet the ultimate success of their arms may depend upon the co-operation of other bodies of troops who ought to be moving towards the same point at the same time, so the operations of the Improvement Trust against the "moral and physical" evils alluded to in the preamble to the Act, depend for their thorough success on support from other parts of the field. My statistics shew, I think, that the Trust is doing its part well, and that the *immediate* results are good; but we must see to it, that we are not building up with the one hand houses which may, for want of sufficient restrictive and regulative power, become as bad in process of time as those which we are pulling down with the other. We must also continue to look to the habits in the new localities of the people who have been expelled from the old, and by a constant pressure

compel them to distribute themselves, and endeavour to divert from intemperance and improvidence towards house-rent a larger proportion of their earnings.

I am no alarmist; but no one can comprehend the importance of this matter of house construction to the future of Glasgow, unless by placing clearly before his mind two facts:—(1.) The enormous number of dwelling houses being erected from year to year—since 1866 no less than 26,794; and (2.) above all, the small size of those houses. Actually, of those 26,794 built since 1866, 25 per cent. were houses of one apartment, and 50 per cent. houses of two apartments, leaving only 25 per cent. for all sizes above two apartments, and of that, 18 per cent. were houses of three apartments. One cannot be too anxious or exacting concerning the ventilation and general arrangements of such clusters of small houses. Mr. Chadwick has said somewhere that towns might be built by contract guaranteed to produce an average death-rate, according to the honesty and completeness of the sanitary provisions. I do not believe this statement without qualifications; but I doubt very much, if specifications were issued for a town of 26,000 houses, to be erected in hollow blocks containing 200 a piece or thereby, piled up in four flats and a "sunk" entering from the court behind, with inside staircases at the corner tenements, the size of house over all to average 25 per cent. one apartment, 50 per cent. two apartments, 18 per cent. three apartments, and the remainder in larger sizes, whether any contractor would be found willing to guarantee, on such conditions, an average death-rate below 25 per 1000 per annum, and even that only with the proviso that not one of these houses should ever be "made down."

XVIII.—*Air and Water in Relation to Public Health.*

By Dr. William Wallace, F.R.S.E., F.C.S.

[Read before the Society, 10th February, 1875.]

The subject upon which I purpose to address you briefly to-night, is one which is at all times of the utmost importance, but it is of especial interest to the people of Glasgow at the present time. For a year or two past we have earned an unenviable notoriety from the unhealthiness of our city, as evidenced by our excessively high death-rate, and only a few weeks past we were startled by that rate being nearly doubled, with nothing to account for the sudden change but a lowering of temperature, which, in other and more favourable circumstances than those that obtain in Glasgow, would only in a slight degree influence the mortality. I have thought it would have some interest for the members of this Society to have a chemist's views on the relation of air and water to public health brought before them, the more so as it will probably be the means of eliciting in discussion the views of those well qualified to express an opinion, but who are not prepared to bring forward a formal paper on the subject.

The air in its natural state is composed of oxygen and nitrogen very nearly in the proportion of 21 measures of the former or active agent, to 79 of the latter, or inactive or diluting ingredient, together with a variable amount of aqueous vapour (averaging about 1½ per cent.), and a very small proportion of carbonic acid (·033 per cent.), and a still more minute quantity of ammonia. Ozone or oxygen in its active state, may also be considered a constant component of natural air; for although in many situations and at particular times it cannot be detected, we can generally account satisfactorily for its absence. The proportion which the oxygen bears to the nitrogen in pure air is practically constant in all situations—on land and on the sea, at high as well as low altitudes; but all the other ingredients are liable to considerable variations, although, after all, the differences, except in the case of aqueous vapour, are not great, unless the composition is influenced by causes which may be considered

strictly local, such as volcanic eruptions or proximity of towns or public works. Over the sea and for a short distance inland common salt is a constant constituent, although the quantity is exceedingly minute, except during great storms, when it is sometimes carried to a distance of twenty or thirty miles in such quantity as to be deposited visibly on window panes and chimney stalks. The other ingredients of sea water—sulphate of lime, chloride of magnesium, &c.—are of course carried into the air along with the common salt, but the presence of these, with the exception of the sulphuric acid, is not easily detected.

I need not refer to the influence upon the atmosphere of animals or plants, except to remind you that they perform opposite functions, and that the one compensates for the evil done by the other. Animals eat food containing carbon and nitrogen, drink water, and breathe oxygen; and the ultimate results are carbonic acid, nitric acid, and ammonia. Plants, on the other hand, decompose carbonic acid, nitric acid, and ammonia, and out of them and the elements of water elaborate azotised and non-azotised compounds, to form food for animals. So the elements carbon, hydrogen, oxygen, and nitrogen keep circulating, and, if the two kingdoms were equally distributed, the composition of the atmosphere would not suffer any change, but remain constant at all places and in all climates. But here man with his civilisation steps in and erects villages and towns and cities, where hundreds, thousands, nay hundreds of thousands of human beings, are closely packed in crowded streets and still more crowded houses. And, as if this evil were not sufficiently gigantic, he invents processes of burning sulphury coal and making gas and paraffin oil, with which still more to poison the confined air; not to speak of manufactures which further pollute the atmosphere with carbonic acid, sulphurous acid, sulphuric acid, hydrochloric acid, arsenic, and solid particles of various kinds, rendering the pure and balmy air stifling and pernicious to health.

Many of the evils of town life are incurable absolutely, but they are capable of amelioration. If the town is spread over a large tract of country it may be comparatively healthy, but if closely built it cannot possibly be so. Every town should have wide streets, the tenements should be restricted in height, and there should be scattered about numerous breathing spaces in the shape of parks and squares. It is a sadly mistaken policy to allow a town to be built up closely, because as it increases in size and prosperity the ground becomes more and more valuable, and the making of open spaces is necessarily attended with enormous

expense to the inhabitants. This has been the case in our own city, and we are now suffering for the neglect or ignorance of our ancestors in the shape of heavy taxes. That our overbuilt corners of the city should be opened up was inevitable; and I think that every right-minded citizen, every one who values the lives and happiness of his fellow-men—nay, I will even put it upon grounds of self-interest—every one who values his own life and health and those of his family, will cheerfully pay the money required to root out the dark spots of our fair city, its dens of infamy and haunts of disease and death. But our rulers should not end here—they should, as far as possible, buy up the ground in the outskirts of the city, especially at the east end, and lay it out for workmen's dwellings in such a way that overbuilding will ever after be an impossibility.

The atmosphere may be considered to be in its normal condition at any place sufficiently removed from towns and from public works. Dr. Angus Smith, the distinguished Inspector of Alkali Works, has selected Innellan on the Firth of Clyde, and Valencia in Ireland, as giving air of great purity; but as a great many coast and country districts have not been tested, it cannot be doubted that there are many localities both in England and Scotland where the air is equally pure. It is easy to analyse air as regards the proportions of oxygen, nitrogen, aqueous vapour, and carbonic acid; but the quantities of other ingredients, such as sulphurous and sulphuric acid, hydrochloric acid, and free and "albuminoid" ammonia, are too minute to be estimated by ordinary chemical processes, or to be expressed in percentages, and are stated by Dr. Smith in grains per million cubic feet of air. Yet these impurities exercise an extraordinary influence on health, and make all the difference between a country life and a residence in a crowded manufacturing town, such as Manchester or Glasgow. As regards the sources of the various impurities, carbonic acid results from the breathing of men and animals, and the ammonia and nitrogenous organic matter are referable to the same cause, at least in great part. The sulphur acids are produced, together with carbonic acid, by the combustion of coal and other varieties of fuel, and of coal gas; while alkali works, copper and iron smelting works, and other manufactories, contaminate the air with sulphuric, sulphurous, and hydrochloric acids, arsenic, and other impurities. The only legislative enactment dealing with gaseous impurities in the air is the Alkali Act, 1863, and the only gas of which it takes cognisance is hydrochloric acid, of which in former years an immense quantity was thrown into the

air, to the great detriment both of animal life and vegetation. Dr. Angus Smith, the chief inspector under this Act, is endeavouring to move the Government to extend the Act to sulphurous and sulphuric acids, the quantities of which that are evolved from the roasting of minerals, and from smelting and vitriol works, is something appalling. For instance, there is a district at no great distance from this city where many thousands of tons are roasted every winter of a kind of ironstone called slateyband, which contains from 6 to 12 per cent. of sulphur, or about 9 per cent. on the average, and about $\frac{8}{9}$ of this are thrown into the air, rendering the whole district for miles round almost uninhabitable. 1000 tons of the ore would yield, if heated in the usual manner, 300 tons of vitriol of 140°. I have calculated that in one particular winter, in the district referred to, enough sulphur was burned off to produce 20,000 tons of vitriol. The evil in the district of Wales where copper smelting is carried on, is probably even greater, and in vitriol works also there is usually much carelessness, and sulphuric acid vapour escapes in such quantity as to render the air in the vicinity of these works very unwholesome. I believe that sulphurous acid is comparatively harmless to animal life, and we know that it is a powerful antiseptic. But it is readily converted into sulphuric acid, and in that condition it is very destructive. In the roasting of the sulphury iron ore to which I have referred, there are two distinct stages. At first a low combustion takes place, sulphurous gas is abundantly formed, but there is at the same time produced a large quantity of the ferric sulphate, which may be observed on the top of the bings in yellow masses, often mistaken for sublimed sulphur. At a subsequent stage of the combustion, which occupies several months, a higher heat is developed, and sulphuric acid is freely evolved, producing an intensely stifling gas, the effects of which on vegetation I have traced, in the direction of the prevailing winds, for two or three miles. It is only in towns, however, that any legislative enactment is likely to be introduced, and hence the law will probably be confined to the operations of alkali and other chemical works and glass works. Dr. Smith holds the opinion, and I quite agree with him, that at the present time the evil arising from the escape of sulphuric acid greatly exceeds that resulting from hydrochloric acid. It is right, therefore, that an efficient check should be put upon manufacturing chemists as regards this acid.

Glasgow, by its position and surroundings, is particularly ill adapted for chemical works. We are in a valley to some extent, and our soil is very retentive, consequently the air is colder and

damper than in most districts of Scotland; and in certain winds, particularly those from the east and north-east, the vapours from the various chemical works hang about the city for days together, rendering the air positively unfit for respiration.

In dwelling-houses we have the results of the breathing of the inmates, as well as the invisible perspiration from the skin, producing carbonic acid and minute quantities of various organic compounds, which give a peculiar "closeness" to the air of an overcrowded apartment. The evil is greatly augmented at night when gas is burned, producing much carbonic acid and also a considerable quantity of sulphurous acid. An ordinary jet of gas will vitiate air to as great an extent as the breathing of three men; and as it is not uncommon, in a sitting room of moderate dimensions, to have three or four such jets burning, it is evident that even with only two or three persons in the room it may be considered overcrowded. The heat evolved by the combustion of the gas increases the evil, for it is an ascertained fact that impure air which can be breathed with comparative impunity when its temperature is only 50° or 55°, becomes positively unbearable if the temperature is raised to about 70°. It is rather singular that the feeling of oppression experienced in an overcrowded room, or in an unventilated hall or church, gives rise to the idea that the air is very hot, and I have often been surprised to learn in such cases, on examining a thermometer, that the temperature was quite moderate. When the air is pure, as for instance in a hot-house, a temperature of 80° or so can be borne for a considerable time without inconvenience; but when air is impure and hot also, the effect is very unpleasant, and even in some cases dangerous. I am very unwilling to pass the strict limits of my own profession, knowing well the errors into which men are likely to fall when speaking of things of which they have an imperfect knowledge; but I think I may venture to say, that the evil effects of breathing impure air—that is, air containing an abnormal quantity of carbonic acid, attended with a diminished quantity of oxygen—are due primarily to an imperfect oxydation of the blood. This, if continued long enough, produces a congested condition of the lungs, and often gives rise to various forms of disease of the respiratory organs. Such effects are witnessed in the case of workmen in crowded rooms—tailors, for instance; and not unfrequently children attending daily a school where ventilation is not properly attended to, acquire the germs of lung diseases, which cling to them through life. In churches, especially during afternoon or evening sermons, the insufficient oxydation of the blood gives rise to drowsiness, which

is often erroneously ascribed to a dull sermon. This condition of body is less likely to occur during the morning service, because the air is then comparatively fresh and untainted.

The difficulty of ventilating a hall filled with people may be best appreciated by considering what occurs when a meeting of several thousands of people, closely packed, is assembled in the open air, especially in a warm summer day. The atmosphere in such cases becomes insufferably heavy, the tainted air passing off too slowly to permit of a sufficient influx of fresh air. Those who have visited the Glasgow Fair on a hot calm July day or evening, will have a vivid recollection of the abominable effluvium caused by the breathing of the crowd of sight-seers. In a hall we have the conditions intensified, and the difficulty of admitting a sufficient quantity of air, without at the same time producing so great a draught as to make the place untenantable, is such that ventilation, in the sense of keeping a hall comfortable for hours together, is almost an impossibility. The nearest approach to it probably is when air is injected by a fan, being previously warmed to about 56° to 60° by passing over steam or hot water pipes. This plan has been found exceedingly efficacious for hospitals and workhouses, and has given most excellent results with patients afflicted with diseases of the respiratory organs. Air passed over heated flues is never so pure. The minute particles of organic dust always floating, getting charred, give to the air an unpleasant *flavour*, if I may so express it, and there is almost always a slight amount of diffusion of the gases from the interior of the flues, even if they are made of cast iron.

But it is only in the case of great public institutions that mechanical power can be used for injecting pure air, or what amounts to the same thing, removing that which is vitiated; and in the absence of this many plans have been tried with greater or less success—the best, in my opinion, being M'Kennell's patent (now I believe lapsed), which consists of two concentric tubes, of which the inner and longer tube carries off the heated and vitiated air, and the outer one introduces pure air from the roof of the building, and by means of a deflector is spread over the ceiling, and gradually and almost imperceptibly permeates the entire building. A mere outlet or series of outlets on the roof is useless, or worse than useless. Take, for example, the principal hall in the Queen's Rooms; when it is crowded and the doors are shut, the air immediately becomes stifling, and there is practically no ventilation whatever; but open the doors and a sweep of cold air comes in that, under such circumstances, is more dangerous than the vitiated air itself.

The ventilation of private houses presents still greater difficulties; but many methods have been adopted with greater or less success. These plans have been thoroughly discussed at the meetings of the Philosophical Society and the Architectural Section. Mr. Hoey's is an ingenious plan, and appears to work well, and the old-fashioned Arnott's valve is still used with some success. There are two distinct methods of ventilation followed—those in which the vitiated air is drawn from a point near the ceiling up the chimney, and those which admit fresh air from the outside, and allow the vitiated air to find its way up the vent through the ordinary opening of the grate. There is no good reason why the two systems should not be combined; but I have seldom seen both adopted in the same apartment. I find that a few holes, bored with a $\frac{3}{4}$-inch bit in the top rail of the upper sash of the window, forms an excellent means of ventilating both bedrooms and sitting apartments, and gives practically no draught in consequence of the high elevation at which the holes are placed. An ingenious method has been introduced by Mr. Pennycook of this city, which I have proved to be most successful, and which consists in removing the top bead of the window frame, and forming, by a simple means which I cannot readily explain, a communication with the interior of the room, the whole breadth of the window, and half an inch wide. This space is filled loosely with horse hair, which tempers the current, which would otherwise be too great, especially during high winds, and filters the air from particles of dust.

I shall not at present speak of the impurities of the air resulting from sewage, as this will come before us more naturally when we come to consider the removal of excreta by water carriage.

The subject of arsenical wall-papers, which made a great noise some years ago, has recently been revived, and rightly so, for it is one of those subjects which, at first laughed at, then pooh-poohed, are after all found to have something in them. In this case the impurity is not a gaseous but a mechanical one; and I think it has been proved beyond doubt that in very many cases arsenical wall-papers have caused serious injury to health. It would be well, therefore, that in choosing wall-papers those should be selected that are free from the bright-green colour, consisting of arsenite of copper. To those who have not studied the literature of the subject I may briefly state, that the colour is gradually and insensibly rubbed off the paper, and so diffused in the air; and this is amply proved by the fact that the dust collected in quiet corners of rooms where bright green papers cover the walls, has invariably been found to contain arsenic, sometimes in large proportion.

I do not consider it within my province to speak of the influence of climate, of elevation, and of humidity, and other similar matters, as these, although exercising a marked influence on health, have little to do with chemical science. But I must make a single remark with regard to the effect of light upon air, for that is a strictly chemical point. Light has a wonderful power of enabling the oxygen of the air to attack and destroy the organic impurities that are present, and hence the necessity for light in rooms, as well as free ventilation. An apartment dimly lighted is undoubtedly much less wholesome than one well flooded with day-light; and I may add that there cannot be a greater nuisance in a house than a delicately coloured carpet or other furniture, on account of which it is deemed necessary to maintain a sombre and melancholy gloom.

I have already alluded briefly to the crowded state of Glasgow. This it is unquestionably that is the main cause of our alarmingly high death-rate—a rate that is higher, I believe, than that of any other town of considerable size in Great Britain, and that has increased with the extension of the city. I don't say that overcrowding is the sole cause, but it is probably the principal one. Glasgow, although occupying a large extent of ground, is by far too small for its population; and if we take only those portions of the city that are inhabited by the working classes, we might probably look in vain in any town in the kingdom for such a number of human beings to the acre as we find in some of our lowest districts. We have one evil to contend with in Glasgow which in English towns is avoided, that is, houses of great height. In English manufacturing towns, at least in the district of them occupied by the industrial classes, the streets are as a rule narrow, probably narrower than ours, but the houses are only two stories in height, and each house is complete in itself, or, as we say in Glasgow, "self-contained," so that diseases of an infectious nature are much less likely to spread than when a dozen houses or so all communicate by a common stair. The ventilation of the streets is evidently much more perfect where the houses are only two stories in height than here, where they are as a rule four stories; and if we add the great want in Glasgow of open spaces, not to speak of our defective sewage arrangements, of which I shall treat more particularly by and by, we have a condition of matters which makes a high death-rate inevitable. Dr. Angus Smith's seventh annual report is probably the most valuable contribution to chemical climatology that has yet appeared, and it displays an amount of perseverance that is truly wonderful. He appears to have made literally thou-

sands of analyses of air from every conceivable place—from the tops of our Scottish mountains to the bottoms of our deepest coal-pits. Dr. Smith, though long resident in Manchester, is a Glasgow man, and we can readily understand that he would touch upon our failings and misfortunes as lightly as possible. Yet the picture he gives us is positively appalling. In all the tables of impurities of every conceivable kind, Glasgow is at the bottom of the list. The air here contains more hydrochloric acid, sulphurous acid, and sulphuric acid, more ammonia, and more nitrogenous organic matter, more carbonic acid and less oxygen, than that found in any other large town in the kingdom. Can we wonder then at our high death-rate, and particularly at the prevalence of disorders of the respiratory organs? Can we wonder that our citizens during the summer months fly from the city to the free air of the country or the coast? Can we wonder if our civic rulers endeavour to admit light and air where they are so much needed, and that some of our most philanthropic citizens should have even anticipated the City Improvement Act, and bought up property in the worst localities for the same laudable object? Our City Improvement Scheme has borne fruit, first in the imitation of Edinburgh, and now in the introduction of a Bill to enable all our large towns to adopt a similar improvement scheme without the necessity of procuring a special Act of Parliament.

I am exceedingly averse to introduce into my paper any considerations of a moral character, yet I think it is impossible fairly to discuss the effects of our humid and vitiated atmosphere if we ignore the influence these have on the minds of our ill-housed and ill-fed working population, in causing them to try, vainly as we too well know, to counteract the depressing influences by which they are surrounded by the use, not to say the abuse, of stimulants. In a bright clear atmosphere there is a natural exhilaration of spirits which renders stimulants unnecessary. When our citizens are better provided with air and light than they are now, they will drink less and live longer.

We now come to the consideration of our second subject—water, in its normal condition, and in various states of contamination.

There is not a more beautiful operation in chemistry than distillation, which is constantly in use both in the laboratory and in manufacturing operations, for the separation of a liquid from the impurities with which it is associated. In nature we have distillation on a gigantic scale constantly going on. The bed of the ocean is the still or retort which contains the liquid, the rays of the

sun supply the heat required to cause the necessary evaporation, the clouds and mountain tops supply the place of a condenser, and the earth is the receptacle into which the distillate is received. And here the rectification, so far at least as the solid ingredients are concerned, is most complete, for rain water is remarkably free from solid matter, and differs only from ordinary distilled water in containing oxygen and nitrogen gases to the extent of 6 or 8 cubic inches per gallon, and in the proportion of one part of oxygen to two of nitrogen. This oxygen in water plays a most important part in the economy of nature, and is essential to water used for drinking. Ordinary distilled water is very insipid and tasteless, and unfit for use as a beverage, although it is never entirely devoid of air; but it may be made palatable as well as wholesome by means of the "aerator," which is now usually attached to the distilling apparatus in ships using sea water.

Rain water is never absolutely pure, but the quantity of impurity varies with the locality. The only ingredients in what may be called normal rain water are traces of nitric acid and ammonia, and near the sea traces of common salt, and of course, in still smaller proportion, the other salts present in sea water. In towns, however, and in localities where chemical works and metal-smelting works abound, the rain that falls is largely contaminated with sulphuric, sulphurous, and hydrochloric acids, ammonia, and particles of carbonaceous matter. The quantity depends partly on the character of the air in the town, and partly on the duration of the rain—a slight shower giving rain highly saturated, while a long continued pour gives a comparatively pure water.

Rain water collected in the country is the purest natural form of the liquid. It saturates the ground, particularly on the higher levels, and percolating downwards through the soil, it forms rills; these coalescing form streamlets, then rivers, gradually increasing in size until they reach the sea. Frequently these streams or rivers expand into lakes, and these are largely taken advantage of by engineers as natural reservoirs for the supply of towns; but in the absence of these, artificial lakes are made by damming up valleys through which streams flow. All lakes, however, are not equally suitable for the supply of towns, for although the water is generally pure so far as regards contamination by sewage or by chemical manufactures, it is very frequently so loaded with peaty matter as to be unsightly in colour and disagreeable to the taste. Even the water of Loch Katrine, although collected chiefly on rocky ground, has a yellow colour, which becomes very distinct when com-

pared with distilled water, and yet the quantity of organic matter is less than a grain in the gallon. Waters collected upon peaty ground have the disadvantage of being exceedingly irregular in composition and colour. During dry or moderately dry weather, water collects on the hill-tops, and forms what are called "hags" or deep holes or depressions, where it becomes fully saturated with vegetable matter. Then when heavy rains fall, this impure and darkly coloured water is washed into the streams and lakes or reservoirs. There are two simple methods of estimating the relative colours of such waters: one is to fill long glass tubes and look through them against a sheet of white paper; another to sink a white plate in the water until it is lost to sight.

When water collected upon high levels, instead of flowing off into streams, sinks deep into the ground, and after passing through a greater or less extent of rock or soil appears at a lower level, it constitutes what are called springs. For example, the city of London rests upon the chalk strata, but below it is the greensand formation, which, forming a basin, crops out all round at a radius of about twenty miles, and water is collected abundantly, and appears in London when the chalk is bored through. It is this water that is used by the London brewers. The same formation exists in Paris, and there the water ascends through bores with such force that it shoots up to a considerable height above the surface of the ground, constituting Artesian wells. In country places generally, where there is no regular gravitation supply, wells are the only available source of potable water; while rain water, collected in barrels or tanks, is employed for washing, for which purpose well or spring water is, from its hardness, unsuitable. The use of rain water ought to be strictly confined to washing and cleansing purposes, as it is, as collected on the roofs of houses, always more or less impure from the washing off from the slates of organic and other matters deposited during dry weather. This when collected in barrels or tanks decomposes, and the water becomes putrid, and consequently unwholesome. Another evil attending the use of rain water depends upon the extremely rapid action of this variety of water upon lead, which renders its collection in leaden cisterns a frequent source of danger. I recollect of a case which occurred in a small town not far from Glasgow, when nearly all the pupils in an extensive boarding school were suddenly seized with symptoms of lead cholic, arising from drinking rain water which had been collected in a leaden cistern. There are some localities where it is impossible to obtain a supply of good water from wells, and it is important in

such cases to collect and store rain water in such a way as to make it available for all domestic purposes. The best way to effect this is to construct an underground tank of bricks, lined with Roman or Portland cement, and to lead the rain water into this after being passed through a filter of animal charcoal. The tank should communicate with the air by means of a tube of six or eight inches diameter, and surmounted by a Muir's four points ventilator, which will ensure a current of air on the top of the water at all times. There should be no leaden pipes used for the water—all should be of iron, or of lead lined with tin.

But to return to the subject of wells. These, when situated in towns or villages, are almost always contaminated to a large extent by drainage from cultivated and often heavily manured gardens, from cesspools, dungsteads, stables, byres, and pigstyes. The wells are often little more than mere holes sunk a foot or two in the ground and roughly built with stones, and I have frequently seen them placed with the utmost ingenuity, so as, if possible, to catch every available drop of the drainage of a byre, pigsty, or necessary. The deepening of wells does not necessarily give pure water, even if all the surface drainage is carefully excluded by puddling, for the water may come from a distance, and appear at the bottom of the well as a spring, and yet the water may be very impure. It is only in very bad cases that we find in wells the presence of recent sewage contamination, for in percolating through the soil the organic matter is oxydised, and the nitrogen appears in the form of nitric acid combined with magnesia or lime. Such waters may not be immediately hurtful, but they are at all times dangerous, and especially during the occurrence of epidemics, when they appear to disseminate the germs of disease. But in some cases the sewage matter passes direct into the wells without undergoing oxydation, and such wells give rise to typhoid fevers and other forms of disease, even where there is no epidemic raging in the locality. Of all the well waters I have examined, and I have tested a great many, by far the greater number were contaminated with sewage to such an extent as to render it extremely doubtful whether they should be used at all. And yet such water, unless polluted by what may be called fresh sewage, is generally colourless, bright, cool, and fresh to the taste; and it is not, therefore, astonishing that country folks should be unwilling to give up the use of their wells, especially when they are required to pay for a supply by gravitation. It is therefore necessary, in many cases, for the local authority of a village or country district to use sharp coercive measures,

and to peremptorily close such wells as are manifestly dangerous to health.

Rivers and streams are also liable to pollution by sewage and the by-products of certain manufactures, such as paper-making, wool scouring, and the refuse of paraffin oil works, distilleries, and various chemical operations. As regards the influence of sewage, it must be considered with reference to quantity. For example, the drainage of a small village somewhere about Tintock would not perceptibly damage the Clyde at Glasgow, for the animal matter would be completely oxydised and rendered harmless. But when we throw into the Clyde the excrements of half a million of people, we tax the powers of water and air too severely, and the river becomes a gigantic cesspool. And yet I believe I am correct in saying that the stinking condition of such rivers as the Clyde, is about the least of the evils connected with our present system of getting rid of our excreta. No doubt travelling on the river in summer is very unpleasant, and we are all heartily ashamed of strangers seeing our seething puddle at the Broomielaw; but it has by no means been satisfactorily proved that the disgraceful condition of the Clyde is directly dangerous to health. But when we examine more minutely into the matter, and look further into the system of water carriage for excrementitious matters, we find in our own homes the true danger of the system, developing itself in fevers, diphtheria, and perhaps other forms of disease. It is curious to reflect that in this wonderful age of progress we should in one matter, and that one which is intimately interwoven with our daily life, have retrograded instead of advancing, and this not only in regard to health but also in an economic point of view; for sewage has a considerable value, the produce of Glasgow being worth nominally—that is, it would be worth if converted into a marketable form—£250,000 a year. This is a large sum of money, and it is evident that if we spent a half or even three-fourths of this sum in producing the article required by farmers, we should still be gainers to a very large amount. However, the main consideration is to get rid of our excreta in such a way as to avoid a nuisance in our houses and in the river. I have to confess that in the matter of the disposal of sewage I am something of a turncoat. Only a few years ago it appeared to me impracticable to employ any other means than water carriage to convey away the sewage of a population who had become habituated to the luxury of water-closets. I did not see any solution of the opposite system, except the dry-earth closet, the quantity of earth required for which is about four times that of the excreta, and I found by a

simple calculation that the amount of earth necessary, the number of acres of land required to be stripped of its soil, and the enormous expense of cartage to and from the city entirely precluded the possibility of its application to a large town, although in a village it might do very well. But other methods have since been proposed, and what appeared only a few years ago impossible now appears to be capable of a practical solution.

This subject is now engrossing the attention of all the large municipalities in the country, many of whom are precluded from admitting their sewage into the rivers upon whose banks they are built, and it will undoubtedly be a subject of paramount importance for many years to come. The idea of irrigation has been carried out to a rather large extent, and upon the whole I think it may be regarded as a failure; while the processes by which it is proposed to extract from sewage its manurial value and then pass it in a pure state into the rivers, will not bear scientific investigation. It appears to me that to deal with sewage we must avoid producing it —keep the sewers for their legitimate use of carrying off surface water and kitchen slops, and convert the excrementitious matter into a form in which it can be utilised for manurial purposes.

Unfortunately, sewage is not the only source of pollution of our rivers. If we go to the River Almond, which flows into the Firth of Forth at Cramond, we find the whole stream and its tributaries, the Beuch Burn, the Brox Burn, the Briech Water, the Linhouse Burn, and the Mid-Calder, frightfully polluted with paraffin oil products, and entirely devoid of fish, except at points above the various paraffin oil works. Again, the North Esk is extensively polluted by paper mills, and other rivers and streams are destroyed by distilleries, sugar refineries, wool scouring, flax steeping, linen and jute bleaching, starchmaking, dyeing and calico-printing, tanning, and chemical manufactures. In very many cases fine streams are transformed into unsightly and stinking puddles. As examples of pollution by dyeing and calico-printing we may take the Cart, with its tributary the Levern; and the Glazart, a fine stream which takes its rise in the hills above Campsie Glen, and joins the Kelvin near Kirkintilloch. Turkey-red dyeing, as carried on on the banks of the Leven, pours an immense quantity of dyeing materials and chemicals into that river, but the volume of water is so great that the extent of pollution is comparatively small, although still serious. The streams in the neighbourhood of Dundee are extensively polluted by the results of linen and jute bleaching and dyeing, and all the streams about Greenock are rendered useless for all ordinary

purposes by the operations of the sugar refineries of that town. I need not dwell further upon these matters, which have been fully treated in various Blue-books issued by "the Commissioners appointed to inquire into the best means of preventing the pollution of rivers." It is obvious that much of the refuse matter at present allowed to find its way into our running waters might be kept out by processes of subsidence and filtration, and in such cases there would be little hardship in compelling the manufacturers to separate the insoluble impurities before running their refuse into the streams. But soluble salts and compounds cannot be so removed, and where these are present in such proportion that the drainage after dilution with the body of the stream is too impure for fish to live in, or to be employed for its primary uses, other means require to be adopted if the present unsatisfactory state of the rivers is to be improved. In the case of paraffin oil no course is open but to evaporate all the refuse liquid matter, and this is actually done at some works. Why, then, should it not be done in all, and so permit a delightful district of country to be restored to its pristine condition? The Commissioners have tested the process of filtration through earth and through animal charcoal for water polluted by dyeing operations, and both were found to effect an immense improvement. In other instances, I believe, it is possible to make the refuse matter a source of profit; but even in such cases manufacturers will rarely adopt preventive means until compelled to do so by force of law. Distilleries produce an enormous quantity of a liquid called "pot ale," which contains an amount of nitrogenous organic matter which would, I believe, amply repay the cost of evaporation, especially if the water were first drained away as far as possible. But we wait for further legislation regarding the pollution of rivers; at present prosecutions can only be instituted by private individuals, and the expenses of such cases in the Court of Session are so enormous, and the polluting interest, if I may so call it, is so powerful, that few actions are raised. I trust, however, that a better time is coming; and as it has been found that the emission of smoke can be prevented without, in general, incurring additional expense for fuel, and sometimes even effecting a saving; so it will be found that if legal enactments make it penal to pollute rivers to an unwarrantable extent, means will be found to prevent the pollution without much extra cost, and sometimes with pecuniary benefit. As an instance of the latter, I may refer to the great Esk pollution case. This was an action brought by certain proprietors of land against the papermakers on

the Esk, the result of which was, that the latter were compelled, under heavy penalties, to keep out of the Esk a large proportion of the materials by which the river was formerly polluted. It was now found that the caustic soda, which was one of the principal causes of the evil, could be recovered at trifling cost; and at the present time the recovery of the soda, instead of being a hardship, as it was at first considered, is a source of large profit, and is readily adopted even by papermakers who are not under any obligation to do so.

I do not purpose to-night to enter into the various plans that have been proposed to remedy the evils of which I have spoken. The approaching visit of Sir John Hawkshaw, for the purpose of taking evidence on the subject of the purification of the Clyde, will afford the opportunity of discussing the matter in a thorough and satisfactory way.

In conclusion, I venture to hope that when all the means of ameliorating our condition have been adopted—when the City Improvement Scheme is completed, and air and light admitted where they are imperatively required—when a new system of sewage is inaugurated, and we are no longer haunted with sewer gas, and our once noble river is restored to something like its pristine purity—when ameliorated conditions of life remove from our lower population much of the temptation and incentive to intemperate habits; I fondly cherish the hope that we shall be better and happier citizens, and that Glasgow, despite her many shortcomings, will long continue to flourish.

XIX.—*Notes on Niagara, &c.* By Mr. William Keddie, F.R.S.E.

[Read before the Society, November 18, 1874.]

Writers who have described the Falls of Niagara have given expression more or less vivid to the effect produced by the spectacle upon their own minds; but it may be doubted whether either pen or pencil has ever conveyed to other minds a true conception of what it is in reality. Some people are disappointed with the first view of Niagara. This must be due, in a measure, to their visiting it with exaggerated expectations and erroneous notions of what they come to see; in some degree, also, to the difficulty one feels in estimating its imposing magnitude and power on a first examination. It is a common and just remark that the falls are little indebted to the effect of the surrounding scenery. There are waterfalls here at home (Foyers is one of them) deriving half their attractions from the accessories of cliffs and deep wooded ravines, which in themselves would be objects of picturesque beauty were the torrents dried up. The river scenery of Niagara, above and below the falls, is not without many pleasing features, but it is dwarfed in presence of the one prominent and absorbing object. *Magnitude* and *simplicity* are the two qualities whence this imposing spectacle derives, in the main, its fascination for the observer. Like all things in nature and art which combine harmony of proportion with grandeur of dimensions, the Falls of Niagara appear at first sight less than they really are, and they grow upon the mind, both in bulk and beauty, by every successive visit. My temporary residence was at Thorold, seven miles off; but I obtained a lodging in the little village of Drummondville, within fifteen minutes' walk of the falls, and for five days I explored the Rapids and the Cataracts at nearly all the available points, viewing them in every direction and in a variety of atmospheric conditions, and I felt that Niagara had never appeared so great and beautiful as when I lingered for the last time in its august presence.

There are, as is well known, two falls—viz., the Horseshoe Fall, on the Canadian side, and the American Fall, on the opposite side

of the river, with Goat Island, belonging to the Americans, placed amidst the Rapids like a breakwater, and dividing the current as it rushes towards the precipice. The banks of the river above the falls are flat, but richly wooded. In laying out the grounds of Goat Island, which has been done without materially disturbing its primitive forest, the Americans have exhibited a degree of taste and enterprise which has not been imitated on the Canadian side, except in the fine demesne named Street's Islands, a private property, from which, as well as from Goat Island, a commanding view of the Rapids is obtained. The deep ravine through which the current flows on emerging from the gulf under the cataract, presents on its wooded slopes a refreshing margin of verdure, while the surrounding country is in summer parched and yellow. Some plants, interesting to the botanist, are found on the moist banks of the river, amongst which may be noted a showy purple-flowered species of raspberry (*Rubus odoratus*), which is widely dispersed throughout Canada; a species of *Apocynum*, or dogbane (*A. androsæmifolium*), not less common; *Rhus elegans; Calamintha glabella*, var. Nuttallii, Gr., and *Lobelia syphilitica.* In Street's Islands I observed the royal fern (*Osmunda regalis*) in a somewhat degenerate state as to size.*

The River Niagara flows out of Lake Erie, being at its exit 330 feet above Lake Ontario. For the first fifteen miles it has a descent of about one foot in a mile. On approaching Goat Island its current is greatly accelerated in the Rapids, along which it descends about 50 feet in less than a mile. At the falls it is precipitated over a cliff 165 feet of perpendicular height. The stream then flows seven miles further in a ravine, with a descent of 100 feet, bringing it to the level of Lake Ontario, into which it is at length discharged after a run of seven miles more.

Of the two cataracts, the greater and the more picturesque is the Horseshoe Fall, so named from the curvature in its form. It is about 1,800 feet, or more than the third of a mile, in breadth, an extent which the eye is slow to appreciate. Goat Island, intermediate betwixt the two falls, is somewhat less in breadth; and the American Fall is about 600 feet wide. The latter forms nearly a straight line; but such is the abrasive force of the torrent, that it

* The following plants occur near Thorold, and on the Welland Canal:—*Asclepias Cornuti; A. incarnata; A. tuberosa; Podophyllum peltatum; Phytolacca decandria; Calla palustris; Sagittaria variabilis; Cephalanthus occidentalis; Asimina triloba* (the North American Papaw); *Sanguinaria Canadensis.* The lowly and beautiful *Linnæa borealis* was found growing profusely in stations so remote from each other as the heights of Point Lévis at Quebec, and Nepigon Bay on Lake Superior.

is steadily wearing away the rock over which it descends; and I was informed by an accurate observer, the Rev. Mr. Bartlett, whose mansion is situated on a plateau overlooking the Canadian Fall, that both the cataracts have perceptibly altered their form since he took up his residence there some years ago—the American Fall, in particular, having shewn a decided tendency to take on the crescentic shape, which contributes so much to the graceful appearance of the larger cataract. Goat Island is also meanwhile slowly but steadily contracting its dimensions, under the influence of the current which it encounters on both sides. The effect of this abrading action upon the two falls and the intermediate island, after the lapse of the next two centuries, will probably be not less remarkable than the change which has passed upon them both since 1678, when Father Hennepin, the French missionary, drew the picture of the falls which is copied from the original in Sir Charles Lyell's work on America. The remaining portion of what was long known as the Table Rock, on the Canadian side, was blasted by gunpowder early last year (1873), under a mistaken impression that it was beginning to give way below. A similar misapprehension as to the stability of the well-known Terrapin Tower, on the American side, led to its being demolished about the same period.

The spray of the torrent is often wafted from the gulf to a great height above the falls, and descends in drenching showers; or it is projected in sudden bursts from the surface of the heaving gulf, caused apparently by the escape of the imprisoned air; or the mist rises from the surge and moves down the river in tall perpendicular columns. In sunny weather the spray is surmounted by an iris, the serene beauty of which forms a singular contrast to the incessant turmoil of the cataract and the abyss into which it descends. My first view of the Horseshoe Fall was enhanced by the presence of the iris, which arched it over like a rainbow; and on my last visit the arch extended from the Canadian to the American Fall, embracing them both.

The sound of the falls is indescribably grand and impressive. It is "the voice of many waters," and we may imagine its power and resonance when we think of Niagara as a narrow cliff over which is precipitated the outflow of three of the most capacious reservoirs of fresh water in the world, being the drainage of half a continent. At night, if the wind happened to be favourable, I heard the *sough* of the falls seven miles away, when it resembled the sound of waves breaking upon a distant sea-shore. On some occasions it is heard at Toronto, which lies right across Lake Ontario at a distance of 45

miles. And yet when you are standing on the bank of the river overlooking the gulf, the sound is not overpowering; it only becomes deafening when you descend into the ravine close to the falls; but both above and below the tremor of the ground is very perceptible. Writers have endeavoured in vain to describe the sound by any sufficiently definite term. It is not a roar nor a rumble—it is not like thunder nor the discharge of distant artillery. Captain Basil Hall employed a prosaic similitude, but one that comes nearest to the truth, when he compared it to the "deep, monotonous sound of a vast mill."

One of the most attractive features of the falls is the green, or rather bluish-green colour of the water. This is displayed particularly in the Horseshoe Fall, and at that part of it where the thickest mass of water is projected over the cliff. More than a third of the fall is green, the thickness of the devolving torrent at this point being estimated at 18 or 20 feet. The river preserves more or less of a blue-green colour in its course along the ravine for several miles, as is distinctly observed even down as far as the Whirlpool. In the perfection of its purity and lustre, as seen in fine weather at the falls, the intense green was a reproduction, upon an extended scale, of the colour exhibited by some of the icebergs seen on the coast of Newfoundland. The same phenomenon I had previously seen in the crevasses of the Mer de Glace in Switzerland, and also in the water of the Swiss lakes. The Lakes of Geneva and Lucerne are of the same colour as the River Niagara below the falls. Where the Rhone emerges from the Lake of Geneva, starting upon a career of swiftness as well as strength, which has won for it the epithet of the "arrowy Rhone," the stream as it breaks over its rocky channel appears of a bright azure hue, which it retains for about a mile of its course, when it is deprived of its distinctive colour by becoming commingled with the muddy waters of the Arvé. What is the cause of this remarkable colour? It is not, as has been supposed, the effect of atmospheric reflection.

On leaving Canada for the States, and crossing Niagara by the railway suspension bridge, I obtained a passing glimpse of the Horseshoe Fall in a thunder-storm, which threw the whole intermediate valley into shade, while the rain was pouring down in a genuine Canadian torrent; yet even at this distance the beautiful green continued to shine through the gloom, only with somewhat diminished radiance. In like manner, I remember observing the blue surface of the Lake of Lucerne to retain its colour during a thunder-storm, when seen from the heights of the Righi through mist and rain, and when the sky was obscured.

Dr. James Forbes observed snow amongst the glaciers becoming blue, when penetrated a few inches from the surface, during a snow-storm, when the sky was of a leaden hue. He ascribed the colour to the purity of the water, whether fluid or congealed. Sir Humphrey Davy was of the same opinion. In his *Salmonia* he remarks that the purest water with which we are acquainted is undoubtedly that which falls from the atmosphere. Having touched air alone it can contain nothing but what it gains from the atmosphere. Rain-water cannot be examined without collecting it in vessels, and all artificial contact gives more or less of contamination; but snow, he observes, falling on glaciers, themselves formed of snow and melted by the sunbeams, may be regarded as water in a state of purity. Congelation expels both salts and air from water, whether existing below or formed in the atmosphere; and in the high and uninhabited region of glaciers there can scarcely be any substances to contaminate it. Sir Humphrey chemically examined the water produced from melted snows on glaciers in different parts of the Alps, and always found it of such a quality as to lead him to consider it as pure. "Its colour," he says, "when it lies any depth, or when a mass of it is seen through, is bright blue." He cites the instance of the Lake of Geneva, fresh from sources (particularly the higher Rhone) formed by melting snow, and passing out of it dyed of the deepest azure. But, in point of fact, when the Rhone enters the lake it discolours it throughout a large space, as much as the Clyde in flood discolours the water of the estuary at Port-Glasgow and Greenock. The water of the lake only becomes limpid, when the detritus which it has brought down from its source in the mountains has met with the conditions favourable to its deposition. When the water has been strained of its grosser mechanical impurities, it assumes the azure hue, although it may be supposed that the stream can scarcely have been charged with such immense quantities of earthy materials, without being, to some extent, contaminated with finely comminuted particles, or at least with chemical impurities which it must retain. In ascribing the purity and blueness of the water to its snowy origin, Sir Humphrey left out of view the muddy condition of the river till it falls into the lake. He was further of opinion that the greenish tint of the ocean depends partly on the presence of iodine and bromine, these substances probably resulting from the decay of vegetable matter. When dissolved in minute portions in water, they give a yellow tint, and this mixed with the blue of pure water would occasion sea-green.

He made an experiment on the water occurring in pools on the surface of the Mer de Glace. He threw a small quantity of iodine into one of the deep blue basins of water on the ice, and diffusing it as it dissolved, with a stick, he saw the water change first to sea-green in colour, then to grass-green, and lastly to yellowish-green. This, he says, he gives not as a proof, but only as a fact favourable to his conjecture.

The question suggests itself in regard to the fresh-water lakes in our own country, and especially those existing in basins consisting of rocks very slightly soluble in water, and therefore, as in the instance of Loch Katrine, extremely pure. Why are *they* not of the blue colour of the Swiss lakes? and why are their effluents not of the hue of the Rhone below Geneva, and the waters of the Niagara below the falls? Loch Lomond is about the same length as the Lake of Lucerne, but possesses none of its blue colour. As Loch Lomond is encircled by micaceous and other schistose rocks, it must contain much less impure matter in solution than the Lake of Lucerne, which is bounded for miles by limestone cliffs. The deeper parts of Loch Lomond and Loch Ness appear black. The Atlantic waves in mid-ocean when looked down upon are black, although in sunshine the spray of their white curling crests reflects an intensely brilliant green with occasional flashes of iridescence. Their blackness was remarked by Dr. Tyndall in contrast with the colour of the water on approaching the banks of Newfoundland, when it becomes less pure, and assumes the characteristic sea-green tint. "The water of the Atlantic," he says, "is practically *black.*" "You go to bed with the black Atlantic around you. You rise in the morning and find it a vivid green, and you correctly infer that you are crossing the banks of Newfoundland." The water of Lake Erie at Buffalo is said to be blue, but of a less deep tint than the water of Niagara below the falls. At the lower part of the lake, where it joins the Welland Canal, I observed no colour. The water of Lake Superior, upon which I was afloat for eight days, including the passage through Lake Huron, was colourless and dark, but when agitated by the paddle-wheel of the steamboat appeared slightly greenish. In neither of these lakes, however, nor in Lake Michigan, so far as I saw it, was there any approach to the brilliant blue-green of Niagara, of the Swiss lakes, and the icebergs.

Lord Dufferin says of a lake in Iceland, that its waters are "as bright and green as polished malachite." "The Gulf Stream," says Prof. Wyville Thomson, "as it issues from the Strait of Florida and expands into the ocean on its north-

ward course, is probably the most glorious natural phenomenon on the face of the earth. The water is of a clear crystalline transparency and *an intense blue*, and long after it has passed into the open sea it keeps itself apart, easily distinguished by its warmth, its *colour*, and its clearness; and with its edges so sharply defined that a ship may have her stem in the clear *blue* stream while her stern is still in the common water of the ocean."—(*The Depths of the Sea*, 1873.)

Dr. Tyndall, in crossing the current which sets in through the Strait of Gibraltar from the Atlantic to the Mediterranean, observed its boundary to be so sharply defined, that "on the one side of it the water was a vivid green, on the other a deep blue. Standing at the bow of the ship a bottle could be filled with blue water, while at the same moment a bottle cast from the stern could be filled with bright-green water." Seen from a distance, the Atlantic here had the hue of ultramarine; but looked down upon, it was of inky blackness, qualified by a trace of indigo.

The water in the Polar ice is described by Captain Parry as exhibiting the same fine blue colour which occurs in the Swiss lakes and glaciers.

Dr. Tyndall, before investigating the subject of the blue-green colour of water experimentally, and previously to his having seen the water of Niagara, was led to suspect that the *impurity* of the water of the Swiss lakes has more to do with its peculiar colour, than its supposed freedom from earthy ingredients. Some years ago he expressed his opinion that not only is the detritus brought down by the Rhone not thoroughly strained from the water in its passage through the Lake of Geneva, but that the presence of solid matter held in suspension may actually be *a cause* of the blue colour of the water. Reflecting on the effect of particles suspended in the air, and in various fluids, in promoting or retarding the passage through the liquids of different rays of light—as, for example, "when a beam of white light is sent through a liquid containing extremely minute particles in a state of suspension, the short waves are more copiously reflected by such particles than the long ones—blue, for example, being more copiously reflected than red,"—he asks, "Is it not probable that this action of finely divided matter may have some influence on the colour of some of the Swiss lakes—as that of Geneva, for example?" Then, referring to the Rhone and its tributaries as being all of glacial origin, and therefore charged with the comminuted matter of the rocks over which they have passed, he proceeds—"But the glaciers must grind the mass beneath them to

particles of all sizes, and I cannot help thinking that the finest of them must remain suspended in the lake throughout its entire length. Faraday has shewn that a precipitate of gold may require months to sink to the bottom of a bottle not more than five inches high, and in all probability it will require *ages* of calm subsidence to bring *all* the particles which the Lake of Geneva contains to its bottom. It seems certainly worthy of observation (adds the writer), whether such particles suspended in the water contribute to the production of that magnificent blue which has excited the admiration of all who have seen it under favourable circumstances."

In a "Note on the Precipitation of Clay in Fresh and Salt Water," by our ingenious member, Mr. David Robertson, printed in the *Transactions of the Geological Society of Glasgow*, it is stated that a quantity of clay placed in suspension in a jar of fresh water, continued gradually to be precipitated throughout a period of six months, at the expiry of which the water had become comparatively clear, but still retained a tinge of colour.

The results of some observations made subsequently (1870) by Dr. Tyndall on water obtained at nineteen different points between Gibraltar and Spithead, may be briefly stated as follows:—Three specimens taken from parts of the harbour of Gibraltar, at some distance from each other, are described respectively as "green," "clearer green," and "bright green;" these, when afterwards examined in the laboratory at London, were found, the "green" specimen to be "thick with suspended matter," the "clearer green" specimen to be "less thick," and the "bright green" specimen to be "still less thick." "Thus (says Dr. Tyndall) the green brightened as the suspended matter became less." In regard to water taken from the Atlantic current, already referred to as flowing into the Mediterranean through the Strait of Gibraltar, the examination of the blue water shewed that "in passing to indigo the water became suddenly augmented in purity, the suspended matter having become suddenly less." "Off Tarifa (he continues) the deep indigo disappears and the sea is undecided in colour; accompanying this change we have a rise in the quantity of suspended matter. Beyond Tarifa we change to cobalt-blue, the suspended matter falling at the same time in quantity. This water is distinctly purer than the green." Twelve miles from Cadiz the water is "yellow green," and when examined at home it proved to be "thick with suspended matter." Fourteen miles in the homeward direction, the water changed from yellow green to a bright emerald green, which was subsequently found to have been owing to "a sudden fall in the

quantity of suspended matter." The cause of the *blue* colour of water and ice is explained as follows by this careful observer:— "Water absorbs all the extra red rays of the sun, and if the layer be thick enough it invades the red rays themselves. Thus the greater the distance the solar beams travel through *pure water*, the more are they deprived of those components which lie at the red end of the spectrum. The consequence is, that the light finally transmitted by the water, and which gives to it its colour, is *blue*." Then, how is the *green* colour accounted for? A white dinner plate was thrown into the sea, and as it sank its hue became green; and when the sea was of the darkest indigo the green, or rather blue-green, was most vivid. The same result is seen on throwing a white pebble into blue water. "Break such a pebble," says Dr. Tyndall, "into fragments, each of these will behave like the unbroken mass; grind the pebble to powder, every particle will yield its modicum of green; and if the particles be so fine as to remain suspended in water, the scattered light will be a uniform green. Hence the greenness of shoal water." The author's conclusion therefore is, that "the greenness of the sea is physically connected with the matter which it holds in solution." Two years after experimenting upon the colour of sea-water, Dr. Tyndall visited America (in 1872), and saw Niagara, the green colour of which he thinks is "correctly accounted for" by the results of the observations and experiments thus concisely stated. (See *Hours of Exercise in the Alps.*)

The lowest and oldest system of rocks in America is the Laurentian series, so named from the Laurentide Hills, north of the River St. Lawrence. The system attains a thickness of 30,000 feet of crystalline strata, and in Canada it occupies an area of about 200,000 square miles. The same system has been recognised in our Hebrides, in Norway and Sweden, and in Bohemia, but its greatest development is in North America. In Canada the Laurentian rocks have yielded one well-marked fossil, named *Eozoon Canadense*, a gigantic representative of one of the lowest orders of animal life, the *Foraminifera*. No trace of its existence in our Scottish Laurentians has yet been detected.* It is the oldest organism that has ever been found in the rocks; and, as Sir Roderick Murchison remarked of the *Oldhamia* of the Cambrian system, "the geologist may well look upon it with veneration!" Over the Laurentian rocks in Canada lies unconformably the Huronian system, which in one district, described by Sir William Logan, has a thickness of 18,000

* Gümbel has found in Bavaria a peculiar species of Eozoon, in rocks corresponding to the Laurentian, and which he names *Eozoon Bavaricum*.

feet. The Huronian is followed in the ascending series by the Lower, Middle, and Upper Silurian. The rocks of the Niagara district are—(1.) the Medina, the Clinton, and the Niagara formations, belonging to the Middle Silurian; and (2.) the Onondaga formation, belonging to the Upper Silurian. The upper parts of the series of the Medina rocks are seen in a section 200 feet thick in the channel of the Niagara river, from a quarter of a mile below the falls to Lewiston and Queenston. The strata dip up the stream, and are distinguishable by their varied colours, the series consisting of red shales or marls, with green spots and stripes, interstratified with thin beds of red sandstone. The upper member of this series is known as the Gray Band, which is quarried near Thorold for constructive purposes. Immediately over this band lies the Clinton, consisting of four feet of greenish and bluish argillaceous shales, abounding in some places with Fucoids, of which the most conspicuous is *Arthrophycus Harlani.* This and another Fucoid and a species of Lingula are the only organisms yet detected in the Medina series in Canada; the Arthrophycus is common to both the Medina and Clinton systems, which are closely united in their rocks and fossils. No trace of leaf, or stem, or relic of a land or fresh-water animal has been afforded by the Medina and Clinton beds.

The rocks of the Niagara period abound in Corals and Crinoidal remains, insomuch that some of the beds have been called old coral reefs. The limestones are usually made up of fossils, and are often magnesian. "There is no evidence of the existence of fishes, or of life over the land and in fresh waters," says Dana. The rocks of this period have a very wide geographical range, and along the Appalachian region in Pennsylvania the strata have a thickness of 1,500 feet. The massive encrinal limestone of the falls includes species of Chætetes, Strophomena, Rhynchonella, Athyris, Atrypa, and Spirifera, together with *Calymene Blumenbachii;* while in the underlying shales most of the species contained in the limestone are repeated; and both have species common alike to them and the Clinton groups, such as *Halysites catenulata, Strophomena rugosa, Pentamerus oblongus, Atrypa reticularis, &c.*

Lake Erie is bounded chiefly by Devonian rocks. Sir William Logan observes that the arrangement of the great western lakes is traceable to the disposal of "two distinct parallel zones of strata, the softer members of which have yielded with comparative facility to the wear producing the excavations holding the water." According to this geological result, Erie and the main body of Huron and Michigan may be termed *Devonian lakes.* Ontario, Georgian Bay (a

portion of Huron), its continuation in the channel north of the Manitoulins, and the vast expanse of Superior, are *Lower Silurian lakes.* Towards the lower end of Lake Erie, the country, including Grand Island and Navy Island, consists of the Onondaga (Upper Silurian) rocks.

The slope and precipice over which the rapids and the cataracts descend, consist chiefly of the Niagara limestone and Niagara shale, together constituting the Niagara group. This formation continues northward for about seven miles, through which the River Niagara has excavated its channel. A narrow space is next occupied by the Clinton group of rocks (Middle Silurian). From this point the river descends at the escarpment of Queenston and Lewiston nearly to the level of Lake Ontario, into which it debouches, after flowing through seven miles of Medina Sandstone (also Middle Silurian).

The limestone cliff over which the stream is precipitated at the falls is 85 feet thick, overlying 80 feet of soft and yielding shale, the aggregate height being 165 feet. The subjacent shale being exposed to the action of the spray, is in a state of disintegration, thus undermining the superincumbent cliff; and the huge masses of rock tumbled into the bed of the stream testify to the constancy and efficiency of this process of excavation. The foaming chasm below the Horseshoe Fall is from 200 to 400 yards wide, and its depth is estimated at 300 feet. Along the ravine ploughed through the rocks the river descends 100 feet in seven miles; on emerging at Queenston upon the flat open country, it descends only four feet in the remaining seven miles of its course to the lake. No one can observe the ravine from the falls downwards without being convinced that it has been scooped out of its rocky boundaries by the action of the stream. Sir Charles Lyell observes that—"It has long been the popular belief, from a mere cursory inspection of this district, that the Niagara once flowed in a shallow valley across the whole platform, from the present site of the falls to the Queenston heights, where it is supposed the cataract was first situated, and that the river has been slowly eating its way backwards through the rocks for a distance of seven miles. According to this hypothesis," he continues, "the falls must have had originally nearly twice their present height, and must have been always diminishing in grandeur from age to age, as they will continue to do in future so long as the retrograde movement is prolonged. It becomes, therefore," he adds, "a matter of no small curiosity and interest to inquire at what rate the work of excavation is now going on, and thus to obtain a measure for calculating how many

thousands of years or centuries have been required to hollow out the chasm already excavated."

There is not only evidence that the cataract is steadily receding under the erosive action of the water, but there is historical proof of its having changed its shape, and by so much shifted its position, within the last two centuries. But when we take all the apparent waste of a couple of centuries, and employ it as a chronological scale whereby to estimate the time occupied by the cataract in working its way back from Queenston, we are plainly exposed to serious error, unless we can ascertain that the waste is proceeding at a definite rate. Admitting the want of sufficient data for estimating the rate of retrogression, Sir Charles Lyell is nevertheless disposed to assume that the falls recede one foot in a year—thus allowing 33,000 years for the excavation of the seven miles of rocky channel. Mr. Bakewell estimated that during the forty years preceding 1830, the river had worked its way back, causing the falls to recede at the rate of a yard annually. But all estimates of this sort must be little better than conjectures, so long as we remain ignorant of the conditions in which the work of erosion has proceeded. Unknown causes may have hastened the process at one time, and retarded it at another. Of two things we may rest satisfied, however, that the channel of Niagara has been cut through the rock, by the power of running water—one of the most energetic and constant agencies in modifying the surface of the earth; and that such an operation could, in any circumstances, only be the work of ages.

I botanised in a wooded dell ten miles from Niagara, formed by a small river or creek, as such streams are called, which falls over a ledge of the Niagara limestone, with the characteristic friable shale beneath. There are two cascades of considerable height, known by the name of De Cou's Falls. At the upper fall the underlying shale was worn away to such an extent as to admit of my easily going behind the cascade, where it leaps over the massive ledge of limestone. The falls are not known to our travellers in those parts, but they would make a reputation for a province at home. The shady banks, profusely clad with wood and wild flowers, reminded me more of a Scottish burn-side than anything else that I saw in Canada. Its interest in the present connection, however, consists in its being really a Niagara in little, both as regards geological structure and aqueous action. (Here and elsewhere—from Montreal to Collingwood—was found a graceful fern, ***Adiantum pedatum***; also ***Desmodium acuminatum***, and the Canadian Columbine, ***Aquilegia Canadensis***.)

The presence on Goat Island and on the river banks of beds of gravel and sand, containing fluviatile shells, was first pointed out by Mr. Hall and Sir C. Lyell, as affording evidence of the former existence of a channel of the Niagara at a much higher level, before the table-land was intersected by the great ravine. This fossiliferous deposit is found on both sides of the stream, shewing that the stratum was continuous till it was disunited by the erosive action of the water; and Goat Island remains in the centre of the river, to confirm the evidence of the former connection of the strata. The shells must have inhabited the river when its bed was the gravelly and sandy deposit in which they are now preserved. They belong to species still living in the same waters, and represent the genera Unio, Cyclas, Melania, Paludina, and Planorbis. The existence of this fossiliferous deposit carries us back to a period antecedent to the excavation of the ravine, and the consequent recession of the falls.

It is observed of the fossil flora of the Pliocene epoch in Europe, that although it presents no species which appear to be identical with plants now growing in Europe, there is a remarkable affinity betwixt these Pliocene species and certain North American living plants. Professor Agassiz states, as the result of a comparison made by himself, that the tertiary fossil plants of Europe "resemble more closely the trees and shrubs which grow at present in the eastern parts of North America, than those of any other part of the world. Hence," says he, "the present eastern American *flora*, and I may add the *fauna* also, have *a more ancient character* than those of Europe and of western North America. This is a peculiarity," he adds, "which agrees with the general aspect of North America, the geological structure of which indicates that this region was a large continent long before extensive tracts of land had been lifted above the level of the sea in any other part of the world." He points out an instance of the ancient character of the fauna presented in the fresh waters of North America, including the River Niagara. This eminent ichthyologist had distinguished ten different species of the Garpike or Bony-pike, belonging to the genus *Lepidosteus*, all of which are confined to the lakes and rivers of North America, with the remarkable exception of Lake Superior. This truly North American fish is the descendant of a family which was widely represented in primitive ages by species which have left their remains in the strata of the old red sandstone, the carboniferous and later formations, in Europe, America, and other regions. The Lepidosteus is described by Agassiz as follows:—

"The scales of Lepidosteus are square, and overlap only very slightly. Each scale is composed of two substances,—first, a lower layer of bone, forming that part of the scale which is covered by the next; second, enamel, like that of teeth. The scales are also hooked together, a groove in each, with a hook from the next fitting into it. Nothing of this kind occurs in other fishes of the present day. From these peculiarities I have named the family the *Ganoids*. Their vertebræ are not articulated together as those of other fishes, but unite by a ball-and-socket joint, as in reptiles."

Tracing the progress of his own knowledge of this genus, first in Europe, the author says,—"One step further was made during this excursion (1848) when, at Niagara, a living specimen of Lepidosteus was caught for me, and to my great delight, as well as to my utter astonishment, I saw this fish moving its head upon the neck freely, right and left and upwards, as a Saurian, and as no other fish in creation does." Again, he remarks,—"This Lepidosteus is one of the swiftest fishes I know. He darts like an arrow through the waters, and the facility with which he overcomes rapids, even the rapids of Niagara, shews that the Falls of St. Mary would be no barrier to him, if there were no natural causes to keep him within the limits in which he is found." These latter rapids or falls (known as the *Sault Ste. Marie*), it may be explained, form part of the beautiful stream which issues out of Lake Superior, through an extensive archipelago, into Lake Huron, connecting them both. The total descent of upper and lower rapids is about 22 feet; but the whole difference of level between the two lakes in a distance of 40 miles is only 32 feet. The Lepidosteus inhabits Lake Huron, but does not ascend to Lake Superior, yet it occurs in Lake Michigan, Lake St. Clair, Lake Erie, and finds its way by the Niagara to Ontario, and even down to the St. Lawrence as far as its outlet into the sea. The curious fact of its absence in Lake Superior was referred to by Agassiz as shewing "within what narrow limits animals may be circumscribed, even when endowed with the most powerful means of locomotion, and left untrammelled by natural barriers,"—an observation which, twenty years afterwards, he was able to confirm by fresh discoveries of the same description in the Amazons.—(See *Narrative of Excursion to Lake Superior by Agassiz and party in* 1848, published in 1850).

While at Niagara, in Mr. Bartlett's garden, I first saw the Colorado potato-beetle and its ravages upon the potato plant. It is a formidable little creature, about the size of a pea, tenacious of life, highly reproductive, and seemingly independent of climatal con-

ditions. It has been traced from Nebraska, where it appeared in 1859, to Iowa in 1861, to Missouri in 1865, in which year it had crossed the Mississippi in Illinois, leaving colonies behind it in its progress. In 1868 Indiana was reached; in 1870 Ohio and the confines of Canada, also portions of Pennsylvania and New York. Next year, 1871, a great swarm of these beetles covered the River Detroit in Michigan, crossed Lake Erie, and speedily took possession of the country between St. Clair and Niagara. A writer in a scientific periodical in the States observes,—"Should the beetle once reach the Atlantic coast, and be carried unobserved across the ocean, then woe to the potato-grower of the old country!"

The east and west coasts of North America are rich in the possession of Tortoises (*Chelonia*), twenty-nine species being allotted to the one coast, and the same number to the other. A pretty little fresh-water species, the *Emys* or *Testudo picta*, frequents the streams and ponds between Ontario and Niagara. (A specimen, of which the Carapace was shewn, was taken in the Welland Canal.)

XX.—*On a Waste-Preventing Water-Supply Apparatus.* By Mr. ANDREW CRAWFORD.

[Read before the Society, 10th March, 1875.]

IT is well known that a great part of the water supplied to Glasgow is running continually to waste; and that unless this be checked, the growing demands of the city will require a new set of supply pipes, and probably an enlargement of the sewers. It is well known also that the greater part of the waste occurs at the fittings. The Water Commissioners, alive to these facts, have tried various means of preventing the waste, but as yet evidently with very partial success —as appears from the semi-official statement recently made, that there is as much water uselessly wasted as would supply nearly other three cities as large as Glasgow. Some years ago the Commissioners issued a set of rules or regulations to be observed with respect to the water-supply and the apparatus allowed to be used, which no doubt prevents the waste being greater than it is. But as this is shewn to be so enormous, I have ventured to propose another system of supply-apparatus to remedy the evil complained of. As it happens, however, in some respects to be at variance with the rules referred to, it has not yet received the sanction of the Commissioners, so as to be allowed to compete with existing systems. I hope it will be here considered on its merits.

The object of the apparatus may be briefly stated to be absolutely to prevent the waste which arises from the present imperfect and defective fittings to cisterns and outlets, or from the carelessly leaving open of a valve or tap. It does this by supplying a limited quantity of water (as much as may be desired when the apparatus is ordered) each time the valve is opened, and no more can be obtained until the valve is again shut for a short period.

Fig. 1 shews the apparatus to be applied wherever it is desired to save water or prevent its careless waste. A is a strong air vessel, into which water from the main is admitted at the bottom by the inlet valve C, whereby the volume of air is diminished and its pressure increased, until it equals that of the main. In its

normal state this valve C is open, as shewn in fig. 1. The water in the air vessel is thus in direct continuity with that of the main, of which it virtually forms a part, while, at the same time, the outlet DD is kept firmly closed by the pressure of the main acting on the valve EE, attached to a flexible disc, whose area is greater than that of the valve. When water is wanted, the inlet valve C is shut, and kept shut by the lever G, while a further pressure on the lever opens the outlet DD, whereby the water from the air vessel is discharged by the force of the condensed air. Thus, while the outlet valve remains tight, no water can be wasted; for while the

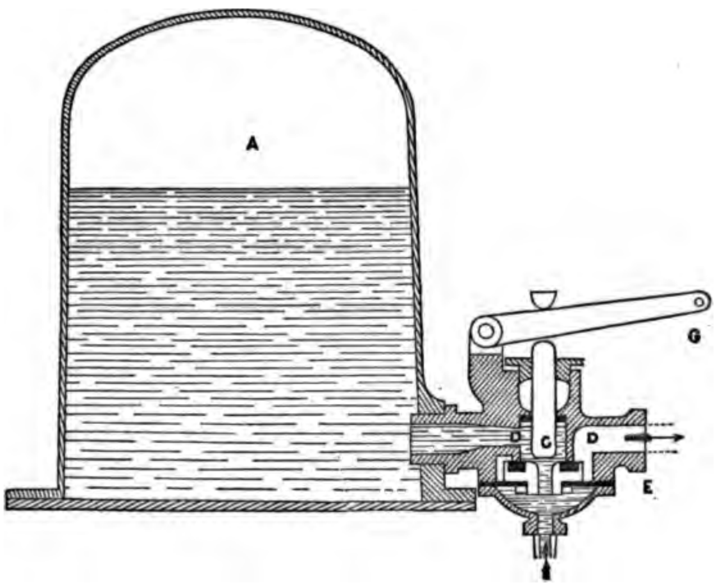


Fig. 1.

outlet is open the inlet is shut, and they cannot be both open at the same time.

The air vessel can be of any capacity, and if for water-closets, can be made to deliver the smallest quantity which any one conceives to be sufficient up to the limits allowed by the Water Commissioners for the supply of the closet. It can be placed at any level above or below the closet. It is economical in its application, inasmuch as pipes of very small bore are sufficient for the supply. The valve cannot be wilfully tampered with so as to make the apparatus run more than the quantity allowed. It is as durable and tight as any

of the stop valves or taps admitted for water supply, and as easily repaired as any of these. The apparatus is equally applicable to wash-basins or sinks, urinals, or drinking-fountains, to all places where it is desirable to prevent waste, without preventing the free use of the water.

[Drawings were exhibited shewing the air vessel and valve attached to a sink; also to a water-closet, with air vessel under the seat, and to a water-closet with air vessel above the seat.]

XXI.—*A Method of Trisecting an Angle.* By Mr. Jas. N. Miller.

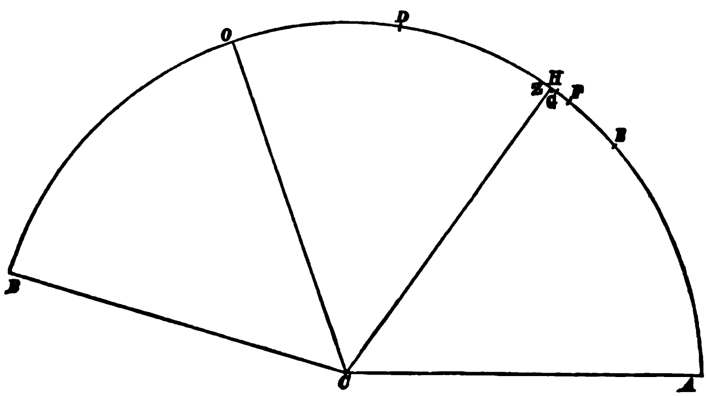
[Read before the Society, 10th March, 1875.]

Let ACB be any angle. With C as centre and any radius CA describe AB, an arc of a circle cutting in A and B the lines CA and CB containing the angle. Bisect the arc AB in D, and the arc AD in E.

Measure from E towards B the arc EF, equal to a fourth of the arc AE.

Measure from F towards B the arc FG, equal to a fourth of the arc EF.

Measure from G towards B the arc GH, equal to a fourth of the arc FG.



Continue indefinitely this operation of measuring towards B, from the extremity next to it of each consecutive increment to the arc AE, an arc equal to a fourth of its immediately preceding arc. In the arc AB, let Z be the point which is the limit to this operation. Then obviously

$$\text{arc AZ} = \text{arc AE} + \text{arc EF} + \text{arc FG} + \text{arc GH} + \&c.$$

$$= \text{arc AB}\left(\frac{1}{4} + \frac{1}{4^2} + \frac{1}{4^3} + \frac{1}{4^4} + \frac{1}{4^5} + \frac{1}{4^6} + \&c.\right)$$

Multiplying both sides of this equation by 4 gives

$$4 \text{ arc } AZ = \text{arc } AB + \text{arc } AB \left(\frac{1}{4} + \frac{1}{4^2} + \frac{1}{4^3} + \frac{4}{1^4} + \frac{1}{4^5} + \frac{1}{4^6} + \&c.\right).$$

Subtracting equation (1) from equation (2) gives

$$3 \text{ arc } AZ = \text{arc } AB.$$

Therefore,

$$\text{arc } AZ = \tfrac{1}{3} \text{ arc } AB.$$

Bisect then the arc ZB in O, and from the points Z and O draw the straight lines ZC and OC. Those lines divide the angle ACB into three equal angles, ACZ, ZCO, and OCB; for those angles are at the centre C of the circle of which AB is an arc, and they stand upon equal arcs of that circle—namely, AZ, ZO, and OB.

Thus, the angle ACB is trisected by the straight lines CZ and CO.

COROLLARY.—By a similar method an angle may be divided into 5, 7, 11, 13, 17, 19, 23, 29, or any number of equal parts.

P.S.—Since the foregoing method occurred to me I have been shewn by Mr. Muir, of the High School, to whom I was referred by Sir Wm. Thomson, a method which, after the first stage, is identical with it, and which he had previously discovered.

XXII.—*M'Kay's Machine for Boring Tube-Plates or other Plates of Metal.* By Mr. William Dron.

[Read before the Society, 24th February, 1875.]

In this age of advancement, when railways are being largely developed not only in our own country but in every other, and when steamship routes are multiplying on every sea, any contribution to the mechanical engineer, by means of which the construction of the necessary engines and boilers may be simplified, should be gladly welcomed, and that more especially in a period of dear labour and "short time." It is with this object in view that I bring M'Kay's tube-plate boring tool before the notice of the Society.

The primary object of the tool is the boring of holes of from $\frac{3}{4}$ to 5 inches in diameter in what are commonly known as "tube-plates."

After marking off the area of each hole wanted in such a plate, a common mode of proceeding is to bore or punch a preparatory hole—say from $\frac{3}{4}$ to $1\frac{1}{4}$-inch in diameter—in the centre of all of the spaces thus marked; fix in the drilling machine a boring bar with a centre-pin to fit this hole and with a cross-head in which two cutters are so placed as to give the exact width of hole required; and then allow the rotary action of the spindle to come into play. Now, to this method there are three very serious objections—viz., I. The time occupied in boring or punching the preparatory hole is *lost* time. II. There is great difficulty in setting the cutters to suit exactly the size of the hole required, and in giving them that correct shape and clearance which is so necessary. III. There is great danger of your tools breaking when just completing their cut through the plate, on account of the downward pressure of the spindle and still more on account of the "drop" which all vertical boring-machine spindles have more or less.

Another method which is sometimes adopted, is to use much the same kind of tool-holder as that now described, but with a spindle movable in the centre of the boring bar, and having its end like an

ordinary lathe "centre," brought down to the tube-plate at the centre of the space marked for the hole, and pressed firmly against it by means of a lever and weight and suitable connections. A slight variation of this is also found, consisting in the application of a spiral spring at the top of the centre spindle, or round the outside of the pillar of the boring bar, but still acting on the centre spindle.

To these two methods of boring the second and third objections, already stated, more particularly apply, but are entirely obviated by the use of the tool I now proceed to describe.

The part of the machine at the top (see figs. 1 and 2) is made round for convenience; it can, however, be made square or circular and tapered to suit the vertical spindle to which it is to be applied. The three chambers for the reception of the central and two side spindles are bored out of the solid metal. The spindles or rams are made of steel, the two side ones having a boss for carrying the cutters, and the upper ends of all three being turned down to admit of a cup leather or packing ring being put on to keep them water or air-tight. The central spindle in its vertical position is always in advance of the side ones, so that

Fig. 1.

Fig. 2.

a greater space in the chamber is left unoccupied by it than in the case of the others. Into this space a sufficient quantity of oil or other fluid is put, oil being preferred. The consequence of this arrangement is that when the machine is attached to the vertical spindle, and

brought down to the tube-plate, the oil at the top of the middle chamber is forced upwards and through the small orifices on each side of the chamber, so as to act upon the two side rams and bring down the cutters to their work. Indeed, a uniform compensating action between the side and central spindles is thus secured. The feed motion of the drilling machine being now applied, and the hole bored through, such is the tension of the side spiral springs, that the moment the centre piece which is being cut out gives way, the two side rams with the cutters are drawn up, and thus the tools are prevented at this critical point from being broken.

A marked feature of the machine is the facility with which the cutters may be set and fixed. If it be wanted to bore a $2\frac{1}{2}$ or 3-inch hole a pair of cutters is put in which are marked for this size, and in a few minutes the machine is ready for work; and so easy are they of adjustment, that any ordinary labourer can do it. The only thing required to be attended to is to put the cutters in the rams so that the countersink hole may be opposite the pinching pins.

They can be so made that with each size of machine a variety of sizes of cutters can be employed. Thus—

D	size will bore holes of from		$2\frac{1}{4}$	up to	3	inches.
F	"	"	3	"	$3\frac{3}{4}$	"
G	"	"	$3\frac{3}{4}$	"	$4\frac{3}{4}$	"

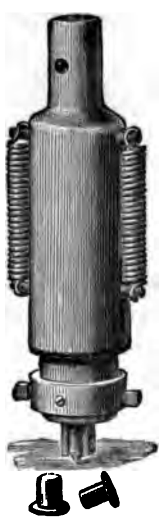


Fig. 3.

Fig. 4.

They can, moreover, be manufactured at a very small cost, and spare sets being kept in stock, if anything were to go wrong with the cutters at work, they could be replaced in a few minutes, thus preventing loss of time in keeping the drilling machine waiting until broken cutters were renewed.

In the case of the smaller sizes, such as from $\frac{3}{4}$ up to 2 inches, instead of the two separate cutters shewn in figs. 1 and 2 it is preferable to use a cutter made from a single cylindrical piece of steel (see figs. 3 and 4) with a hole through it for the passage of the spindle.

I may sum up the advantages of the tool as follows :—

First. It saves labour; any ordinary unskilled labourer can work with it.

Second. It produces good workmanship, as the specimens exhibited abundantly shew.

Third. It effects a great saving of time, more especially in the case of large sized holes.

Fourth. It effects a saving in power, as it is only an *annular* cutting which is made, and not a boring of the circular area of the entire hole.

Fifth. It may be used in boring a series of *intersecting* holes—work which could not be done by an ordinary conical drill, and which would be too expensive to be accomplished by forging.

[Specimens of work done by the tool, including that referred to in the sentence preceding, were exhibited to the audience.]

DISCUSSION ON MR. DRON'S PAPER.

Mr. MENZIES, one of the licensees of the tool, was called upon by the Chairman, and made a few remarks, adverting mainly to the fact that it enabled an unskilled workman to produce more perfect results than the best skilled mechanic could at present do by means of an ordinary drilling machine.

Mr. DEAS spoke very highly of the tool, and expressed his belief that the form represented in fig. 3 would speedily come into extensive use.

Mr. J. P. Smith also affirmed his strong belief in its merits. It was just such a thing as was wanted by engineers, and the feature of having the cutters all made to gauge and ready for use, so that a broken or blunt one could at once be replaced, was most important. At present much time was often lost in sharpening and replacing the ordinary drilling tool, and it was not only the time of the workman which had to be considered, but also the time during which an expensive machine was kept idle. With such a tool as that exhibited by Mr. Dron the time lost in replacing cutters would not be one-fourth of what it was at present.

XXIII.—*Notes of a Tour in Germany, with special inquiry regarding the Provisions for Scientific and Technical Education.* By JAMES BRYCE, M.A., LL.D., F.R.S.E., F.R.G.SS.L. & I.

[Read before the Society, January 27, 1875.]

THE cities which Dr. Bryce had visited, with the main purpose of seeing their schools, were Hanover, Berlin, and Elberfeld; and he had chosen these, as one was the capital of the German empire; another once a royal city, and as yet only beginning to engage in manufactures; while the third has been, for many years, the chief seat of manufactures in Prussia, on account of its proximity to the only coalfield in the whole of North Germany. Being aware of what Mr. Matthew Arnold, and authors who preceded him, had published in regard to education in Germany, and of what Mr. Gill, Mr. Lyon Playfair, Mr. David Sandeman, and others, had written on the subject of the provisions for technical education, he had turned his attention to another branch of the inquiry, the internal organisation of the schools, and the methods of teaching which were pursued in them. As the teaching of science in its bearing on the practice of the various arts was the chief object of inquiry, and as he had long been himself practically engaged in teaching the mathematical and physical sciences, he considered that he had a special qualification for judging how far the inner working of the German system corresponded with what was set forth in the programme of those schools, and in the accounts of the branches which are taught, in such reports as those above referred to; what was the character of the instruction, how it was adapted to the end in view, and what amount of commendation was to be bestowed upon it.—He had been most kindly received by the Directors or Principals of the schools and the various masters, and the utmost facilities had been afforded him for testing the quality of the instruction, by his being permitted to be present while the lessons and lectures on the various subjects were given.

After alluding briefly to the different classes of schools, he described particularly the system pursued at the *Real-schule*, or "practical schools," as they might be called, which he regarded as the key-stone of the whole educational system, inasmuch as they kept up the standard of education in the schools below them, and were an admirable preparation for the schools above them, such as the Polytechnic, the Gymnasium (grammar or classical school), and the University. He explained in detail the system of teaching in these schools, its high character, its practical tendency, and excellent results. The lessons consisted partly of lecture, and partly of examination, so that the attention of the students was constantly kept up; the illustrations—by apparatus in the case of physics, and by specimens in the case of the natural sciences—were ample and excellent. In all the schools the apparatus for physics was extended and beautiful, in some of them the most complete and beautiful he had seen anywhere. Museums of natural history were attached to, he believed, all such schools, certainly all he had seen; but several of them had not proper space to arrange the specimens, and so their usefulness was in some respects marred. In Hanover and Elberfeld this was in course of being remedied by the erection of new buildings. In all these schools instruction in the theory and practice of music was made a subject of importance. In the Polytechnic Schools, the lecture in all the large classes was continuous—examinations and essays being taken, as in our colleges, at a separate hour—the more advanced age of the students not requiring that their powers of attention should have the same stimulus. In these schools, in addition to very fine apparatus and a museum, there was a collection of tools of all sorts, carefully arranged in glazed cases, and labelled. The number of tools, locks, etc., of every possible description in the Polytechnic School at Hanover was seventeen thousand. There was besides a collection of models of all sorts of things employed in the various arts of construction. He considered the system of the *Real-schule* very excellent in every way, and well adapted to develop the faculties of the pupils. There were Entrance and Leaving Examinations, which had a most beneficial influence on the schools above and below them, as keeping up a high standard; while, at the same time, the system was not hampered by a strict curriculum—the tastes of the pupils in their predeliction for certain studies being attended to, so that there was something in the system suited to every taste. The countrymen of Karl Ritter and Alexander von Humboldt had taken care that Geography, mathematical, physical, and descriptive,

should receive proper attention as an independent subject of instruction; and, accordingly, it received the same amount of time —an hour a day for three days in the week—as any other branch, except the mother tongue, and, in some schools, Latin and English. Natural history also was taught in every school—zoology and mineralogy in winter, botany in the early summer; all these branches unsystematically to the younger classes, but according to the best systems of classification to those more advanced. In every case where it was at all possible, specimens were made the medium of instruction; and the pupils were directed, in the case of the wild native plants, and those generally cultivated, to bring specimens to the class-room for the day's lecture. He believed, however, that, except in the case of some schools in Dresden, the practice of taking the students on excursions—which he himself had found most useful and interesting in the case of those studying geology and botany, as well as of visits to factories and workshops for the students of mechanics—was not much followed in the German schools. One admirable feature he found to exist in all of them, the *Real-schule* and Polytechnic alike, that in conducting examinations as little as possible was said by the teacher, and as much as possible of the talk left to the pupil—no bad criterion of good teaching.

Dr. Bryce then described at some length the Polytechnic schools, their courses of united instruction intended for all, and the detailed special courses for the training of an Architect, an Engineer, a Farmer, a Land Surveyor, and a technological Chemist. Each of these ran through several complete sessions of nine months each; and embraced a thorough instruction in every branch of knowledge in any way related to the practice of the particular art. An additional year—for some a fourth, for others a third—was optional, and intended for those whose time and strength enabled them to climb to still higher heights. These detailed courses had a place in the programme of all the Polytechnic Schools over the empire; he need not tell his audience in how few towns in this country students could have access to courses at all approaching to these, and how imperfect usually were the acquirements of young men among us entering on the professions which he had named. He urged the establishment of such Polytechnic Schools in some of the leading towns of Scotland, as Glasgow and Dundee; and pointed out the peculiar facilities which Glasgow affords in two admirable institutions which she possesses, the Andersonian University and the Mechanics Institute (both

holding large and valuable property), for the foundation of a good Polytechnic School, which would tell powerfully in a short time on the acquirements and character of the men engaged in the varied industries of this great and rapidly increasing community. It had always seemed to him doubtful whether in the Race to which we belonged, especially as now placed under the harsh physical conditions of its northern home, it was possible that originality and invention in design could ever be developed like that which marked the races of Greece and Italy placed under sunny skies, in lands teeming with beauty. Our "gifts of nature," and inventive powers went out in another direction; one more *subjective*, less under the influence of existing outward conditions, that, namely, of inventions in science and in the mechanical arts, in which we were unrivalled. There could be no doubt, however, that education directed to this end would in the course of time do much; and he might instance, by way of encouragement, what had been already accomplished in the School of Art at South Kensington. He had spent some time in examining what was there done, on his way home from Germany, in order to compare the work with that of the German Polytechnic Schools; he had been much delighted with all the plans and arrangements for the promotion and teaching of Art; and nothing he had seen in Germany could be said to surpass, if indeed it equalled, what was done in the South Kensington School to cherish and to develop the power of original design.

Dr. Bryce next referred to the magnificent provision made either by the Government or the municipalities, in some cases by both jointly, for the education of girls. It was to be remembered that in all parts of Germany, and in all classes of schools, the boys and girls were educated separately; the prejudice against mixed schools, which Mr. Arnold has shewn to be so rapidly increasing in France that they have been lately abolished in many districts, has always existed in Germany, though such mixed schools are common in Switzerland and some other parts of the Continent. These girls' schools, or *Tochter-schule*, as they are called, afford a course of intellectual and religious instruction, very similar to that of the *Real-schule*, though in some of the subjects the pupils are not carried on so far, and other branches are added, suitable for girls only. He had examined into the inner working of these schools in the several cities, and found them admirably conducted. The classes for almost all the intellectual and moral subjects were taught by men, and of these the great majority, as in the case of the schools already mentioned, had had a university education.

The teaching he had found not less excellent than in the *Realschule* and Polytechnic Schools; and the attention, proficiency, and enthusiasm of the girls were delightful to witness. Vocal music is taught in all these schools; but the numbers who attend are so great, from 500 to 700, that it would be impossible to have instruments for their use. The singing is simultaneous, the teacher giving the pitch by a violin. For young ladies intending to become governesses there is an advanced course of one or two years, and instruction in the art of teaching. The Director or Rector of each of these institutions has constant applications from all parts of Europe for family governesses, and consequently a very large correspondence. One of these gentlemen who presided over the largest and perhaps the most celebrated institution of the kind in Germany, had told him that *the last place* he recommended governesses to go to was Great Britain, on account of the position they would occupy in a family there; he very much preferred to send them to Finland, Russia, and Sweden, where they would not only have larger salaries, but be treated as members of the family. He was obliged to endorse the Rector's statement, and he felt sure there was no one among his hearers who would feel inclined to question its correctness.

In conclusion, the lecturer gave a short account of the efforts made in Berlin by Miss Archer, an Edinburgh lady, who spoke and wrote German like a native, for the improvement of female education among the higher classes, whose practice never had been to attend public schools; and of the noble work now done for this purpose by the Victoria Lyceum, first established by, and still under the direction of Miss Archer, who enjoys the encouragement and active support of the Crown Princess in all her plans for imparting a higher tone to the education of the young ladies of the capital.

XXIV.—*A Method for the Interpolation and Summation of Numerical Series.* By Mr. JOHN DONALD, St. Rollox School.

[Read before the Society, February 10, 1875.]

IF all who have the opportunity of witnessing physical phenomena, were trained to habits of observation, could make comparisons and record them in a numerical form, and were able to reason from the facts known to the facts unknown; we may well believe that our knowledge of science would become much more extensive and definite, and improvement in our manufactures more certain and more rapid.

But I might paraphrase this statement, and attribute the same results to a careful study of series. For it not only enables us to interpret facts when properly arranged and expressed numerically; but there is such a fascination wrought upon the mind by being so exercised, as induces a craving for material upon which to operate, and creates eyes, bodily and mental, ready to see relationships between conditions and changes, which would otherwise be passed by unheeded. Notwithstanding all this, the subject is not generally known; and the reasons are not difficult to find. The methods are numerous, the reasoning to many appears hard to follow, and the formulæ or conclusions are easily forgotten.

I am here to-night to give an outline of a method which requires a very slight knowledge of Algebra, which is more general than any method I have seen, and if forgotten is easily reproduced.

The numbers 1, 4, 9, 16, 25, 36 are six terms of a series. If we answer the questions, What is the twenty-third term? What is the sum of twenty-four terms? &c., we shew our knowledge of the interpolation and summation of series respectively.

Series No. 1.

No. of Term.	Series.
1	1
2	4
3	9
4	16
5	25
6	36

A little consideration shews, that each of the terms grows out of the number of its term in the same way. If the number of the term be squared, the product is the term opposite. If the letter n stand for the *number of term*, the general term of this series is n^2.

Let us examine a series whose general term is known. The series n^3 will do well.

Series No 2.

1			
8	7		
27	19	12	
64	37	18	6
125	61	24	6
216	91	30	6

If we subtract the first term from the second, the second from the third, the third from the fourth, &c., and place the remainders in a column to the right of the series; and if we go on treating each column in a similar fashion, we shall at length find that the differences become nothing. Many series are such that their differences at length terminate. The *number of columns* of differences always indicates the nature of the series. It can be proved that a series whose general term is n^4 must have four columns of differences; n^5, five columns; n^x, x columns, &c. But although the number of columns shews the *power* to which n is raised, it gives no information as to the exact value of the general term. The general terms n^3, $2n^3$, $15n^3$, $\frac{n^3}{2}$, $\frac{n^3}{4}$, &c., would each have three columns of differences.

For the sake of distinction, let us name the numbers 6, 12, 7, 1, which begin the columns, the *initial* differences. If each of the terms of series No. 2 be multiplied by 5, we shall find

Series No. 3.

5			
40	35		
135	95	60	
320	185	90	30
625	305	120	30
1080	455	150	30

that not only is *each term* multiplied by 5, but the initial differences are five times greater, and the general term is also five times greater—namely, $5n^3$. Suppose that the general term of the series 2, 16, 54, 128, 250, 432 is unknown, it may be found.

Series No. 4.

2			
16	14		
54	38	24	
128	74	36	12
250	122	48	12
432	182	60	12

Because there are four initial differences, and the four initial differences 6, 12, 7, 1, shew that the general term is n^3, we have only to find how often 6, 12, 7, 1 is contained in 12, 24, 14, 2, in order that we may find the general term of Series No. 4.

$$\begin{array}{l} 6\ 12\ 7\ 1)\ 12\ 24\ 14\ 2\ (2n^3 \\ \qquad\qquad\quad\ \underline{12\ 24\ 14\ 2} \end{array}$$

By writing series with n raised to the respective powers, and finding the differences as above, we find the following table:—

					$1 = 1$
				1	$1 = n$
			2	3	$1 = n^2$
		6	12	7	$1 = n^3$
	24	60	50	15	$1 = n^4$
120	360	390	180	31	$1 = n^5$.

The above table may be made or enlarged in several ways. In its present extent it is serviceable in interpreting series which have not a higher power than the fifth.

What is the general term of the series 8, 27, 154, 575, 1572, 3523, 6902, &c.?

Series No. 5.

8				
27	19			
154	127	108		
575	421	294	186	
1572	997	576	282	96
3523	1951	954	378	96
6902	3379	1428	474	96

24 60 50 15 1)	96	186	108	19	8	($4n^4$
	96	240	200	60	4	
6 12 7 1)		−54	−92	−41	4	($-9n^3$
		−54	−108	−63	−9	
2 3 1)			16	22	13	($8n^2$
			16	24	8	
1 1)				−2	5	($-2n$
				−2	2	
1)					7	(7

Let U_n = the general term.
Then $U_n = 4n^4 - 9n^3 + 8n^2 - 2n + 7$.
The sixteenth term would be—

$$4 \times 16^4 - 9 \times 16^3 + 8 \times 16^2 - 2 \times 16 + 7 =$$
$$262144 - 36864 + 2048 - 32 + 7 = 227303$$

What is the general term for the sum of the series 1, 7, 19, 37, 61, &c.?

Series No. 6.

1		
7	6	
19	12	6
37	18	6
61	24	6

The sum of one term is 1; of two terms, 8; of three terms, 27, &c., as under—

Series No. 7.

1			
8	7		
27	19	12	
64	37	18	6
125	61	24	6

In order to find the sum of any number of terms of Series No. 6, all that is required is to interpret the initial differences of Series No. 7. But the initial differences of No. 7 are the *sub-initial* differences of Series No. 6. And this holds true universally. But 6 12 7 1 means n^3; therefore the general term for the sum is n^3.

The sum of—

$$3 \text{ terms} = 3^3 = 27$$
$$5 \text{ terms} = 5^3 = 125$$
$$20 \text{ terms} = 20^3 = 8000$$

A body falls 16 feet during the first second, 48 feet during the second second, 80 feet during the third, 112 feet during the fourth. How many feet would it fall during the tenth second, and how many feet would it have fallen altogether in 12 seconds?

Series No. 8.

16	
48	32
80	32
112	32

$$32 \quad 16 = 32n - 16 = 320 - 16 = 304 \text{ feet}$$
$$32 \quad 48 \quad 16 = 16n^2 = 16 \times 12^2 = 2304 \text{ feet}$$

The top row of a pile of balls has 8 in the length and 5 in the breadth; each row contains 1 more in the length and 1 more in the breadth. How many are in the 20th row; and how many are in the 20 rows?

Series No. 9.

40		
54	14	
70	16	2
88	18	2

2 14 40 $= n^2 + 11^n + 28$.
Balls in 20th row $= 400 + 220 + 28 = 648$

$$2 \quad 16 \quad 54 \quad 40 = \frac{2n^3 + 36n^2 + 202n}{6}$$

$$\text{Balls in 20 rows} = \frac{16000 + 14400 + 4040}{6} = 5740$$

If we attempt to treat the series 1, 16, 108, 512, 2000, 6912, &c. as has been done in previous cases, we shall find that the differences do not terminate.

Series No. 10.
1st Degree.

1					
16	15				
108	92	77			
512	404	312	235		
2000	1488	1084	772	537	
6912	4912	3424	2340	1568	1031

But if the initial differences be formed into another series,

Series No. 10.
2nd Degree.

1			
15	14		
77	62	48	
235	158	96	48
537	302	144	48
1031	494	192	48

we find that the initial differences of the second degree terminate.

The following is a table for interpreting initial differences of degrees other than the first. It is formed from the first table by a law, which will appear simple enough after a little consideration.

$$\begin{array}{r}
1\\
1\\
\hline
1=2^{n-1}\times 1
\end{array}$$

$$\begin{array}{rl}
1 & 1\\
2 & 1\\
\hline
2 & 1=2^{n-1}\times n
\end{array}$$

$$\begin{array}{rrl}
2 & 3 & 1\\
4 & 2 & 1\\
\hline
8 & 6 & 1=2^{n-1}\times n^2
\end{array}$$

$$\begin{array}{rrrl}
6 & 12 & 7 & 1\\
8 & 4 & 2 & 1\\
\hline
48 & 48 & 14 & 1=2^{n-1}\times n^3
\end{array}$$

$$\begin{array}{rrrrl}
24 & 60 & 50 & 15 & 1\\
16 & 8 & 4 & 2 & 1\\
\hline
384 & 480 & 200 & 30 & 1=2^{n-1}\times n^4
\end{array}$$

$$\begin{array}{rrrl}
6 & 12 & 7 & 1\\
27 & 9 & 3 & 1\\
\hline
162 & 108 & 21 & 1=3^{n-1}\times n^3
\end{array}$$

$$\begin{array}{r}
1\\
1\\
\hline
1=0^{n-1}\times 1
\end{array}$$

$$\begin{array}{rrrl}
6 & 12 & 7 & 1\\
-1 & 1 & -1 & 1\\
\hline
-6 & 12 & -7 & 1=-1^{n-1}\times n^3
\end{array}$$

$$\begin{array}{rrrl}
6 & 12 & 7 & 1\\
x^3 & x^2 & x & 1\\
\hline
6x^3 & 12x^2 & 7x & 1=x^{n-1}\times n^3
\end{array}$$

We now find that the general term of Series No. 10 is $2^{n-1}\times n^3$. We have already found that the power 3, which accompanies the

root n, in the expression $2^{n-1} \times n^3$, indicates the number of *columns* of differences; and we now find that the root 2, which accompanies the power $n-1$, indicates the number of *degrees*.

If the initial differences which do not terminate are either a geometrical progression, or can be converted into one, the labour is very much lessened.

Series No. 11.

1st Degree.				*2nd Degree.*				*3rd Degree.*	
5				5				5	
15	10			10	5			5	0
45	30	20		20	10	5		5	0
135	90	60	40	40	20	10	5	5	0

0th Degree.				*– 1st Degree.*				*– 2nd Degree.*			
5				5				5			
20	15			25	20			30	25		
80	60	45		125	100	80		180	150	125	
320	240	180	135	625	500	400	320	1080	900	750	625

Let R = Ratio between a consequent and antecedent.
D = Number for degree—1 for first, &c.
n = Number of term.
A = First antecedent.
U_n = General term.
Then $U_n = (R + D)^{n-1} \times A$.

General term of Series No. 11 as found

$$\text{in 1st } Degree = (2+1)^{n-1} \times 5 = 3^{n-1} \times 5.$$
$$2nd \;\; ,, \;\; = (1+2)^{n-1} \times 5 = 3^{n-1} \times 5.$$
$$-2nd \;\; ,, \;\; = (5-2)^{n-1} \times 5 = 3^{n-1} \times 5.$$

We learn from the above, that initial differences that form a geometrical progression may be interpreted in any *degree*.

Find the sum of the series 9, 9, 47, 95, 205, 349, 579.

The initial differences are found to be

9 0 38 –28 80 –160 320

5	–10	20	–40	80	–160	320	$= -1^{n-1} \times 5$
4	10	18	12				$= 2n^3 - 3n^2 + 5n$
9	0	38	–28	80	–160	320	$= -1^{n-1} \times 5 + 2n^3 - 3n^2 + 5n.$

What is the general term of the series 11, 4, 9, 16, 25, 36, &c.?

Series No. 12.

11					
4	−7				
9	5	12			
16	7	2	−10		
25	9	2	0	10	
36	11	2	0	0	−10

10	−10	10	−10	10	−10	10	$= 0^{n-1} \times 10$
1	3	2					$= n^2$
11	−7	12	−10	10	−10	10	$= 0^{n-1} \times 10 + n^2$.

The numbers 4, 12, 29, 59, 114, 223, 445, 894 are terms of a series whose initial differences form a circle of three figures. The differences never terminate.

Series No. 13.

4							
12	8						
29	17	9					
59	30	13	4				
114	55	25	12	8			
223	109	54	29	17	9		
445	222	113	59	30	13	4	
894	449	227	114	55	25	12	8

The average of circle 4, 8, 9 is 7. And if the series whose initial differences are 7 7 7 7 &c., be compared with Series No. 13 as under

7	14	28	56	112	224	448	896
4	12	29	59	114	223	445	894
−3	−2	1	3	2	−1	−3	−2

we shall find that the differences form a circle of six figures. The difference between the 1st, 7th, and 13th terms are the same, namely, −3. The general term is therefore $2^{n-1} \times 7 +$ the correction corresponding to $\left(\frac{n}{6}\right)_r$ that is, the remainder found by dividing n by 6.

XXV.—*On a Self-acting Railway Train Brake.* By JAMES STEEL, Esq.

[Read before the Society, 24th Feb., 1875.]

CONTINUOUS Brakes have been a desideratum since the projection of the railway system. So early, indeed, did the necessity turn up, that even old George Stephenson himself tried his hand upon one. We are therefore prepared to find that brakes of all kinds have been proposed—water brakes, air brakes, steam brakes, electric brakes, shaft brakes, chain brakes, and even brakes to throw carriages off the line. I can remember, too, that over thirty years ago, when engaged as a mechanic in a railway workshop, the subject was one of constant discussion, and that we used to exercise our wits in the attempt to create a continuous-brake engine; for, by the way, it is not so much a brake as a brake *engine*, or brake *actuator*, that we want, and have to discuss—that is, an engine to perform the duties of the multitude of guards which would need to be employed, were the public insisting that railway companies should put a brake on every carriage of a train. I shall, however, in the present paper, use the simple term *brake* for the sake of brevity.

The want of a brake engine has, in this country, been felt more by the public than by the railway companies, as custom has not imposed upon the latter the practice of having a brake and a brakesman to each carriage, as it has in America and in countries where trains have to traverse mountainous districts. In the United States the large cars have each an appointed brakesman to act in concert with the driver, who gives the signal for action from the whistle of the engine. In the Highlands of India and South America, and in the Alpine regions of Europe, a guard to each carriage is a necessity for the safety of passengers and those engaged in the conducting of trains. On the other hand, however, we in this country employ

fewer guards now than was done (so far as my memory serves me) in the time of my early railway experiences, and this notwithstanding the greater speed at which trains travel. I can remember a large number of "dickies" being mounted on the fronts of the carriages, and I think there were also more of the carriages carrying brakes.

Being an interested party in this matter, it would be somewhat ungracious in me to dictate to railway directors how they should manage their affairs; but it is not taking a great liberty to say, that it would be far from unreasonable in the public to demand that the carriages in which they travel should each have a brake attached, worked by the hand or such other means as might be found best. The locomotive and tender have enough to do with their own accumulated momenta, without having it left to them to check the momentum of the mass of train surging up behind. To say the least of it, it is anomalous that railway companies should pile up a Titanic power on their locomotives to urge trains forwards, and should at the same time neglect all means of counteracting the effect of this power, when it is leading to imminent destruction. Think of a locomotive and tender of 300 or 400 horse power, weighing 50 or 60 tons backed by a train of some 200 tons more, flying through space at a velocity of a mile per minute, and carrying 600 or 800 precious lives, with stopping appliances scarcely fit to brake an old woman's spinning wheel!

Wherever the fault of this state of things may have lain in the past, railway directors and officials generally now admit it to *be* a fault, and are, I believe, only waiting for some invention which will fulfil the requirements of the Board of Trade. It is now known that a train fully braked means a train that will stop in one-third of the time of the present partially braked trains; and when I state that on an incline, or in a bad condition of rails, or with both causes in action, a train has often to be braked for a mile before it will stop, it is easily seen that a saving of two-thirds of a mile in the case of only one of two approaching trains means something of importance in the avoidance of collisions. In fact, so far as collisions are concerned, it is admitted by all—except some chronic obstinates—that one collision would not take place for ten which now occur, were continuous brakes in general use. Of course, I am speaking of *direct* collisions, which a few seconds of time and one or two hundred yards saved by brake power would prevent. The Kirtlebridge collision, for instance, would have been mitigated, if not altogether obviated, by a con-

tinuous brake and a good brake engine; and yet we have the startling fact that the money lost on this one accident would have supplied with efficient brakes the whole of the Caledonian passenger plant.

Among the various special forms of continuous brake which have been proposed, I may mention first, *Shaft* and *Chain* Brakes, which have been introduced, but have not met with much success.

Newall's first brake, which may be called a shaft brake, appeared five-and-twenty years ago, and was well tried, as was his more recent patent, yet neither have taken root. Since then we have had Fay's Brake, likewise a shaft brake, which had opportunities of being tested practically on at least one Scotch line, and yet has disappeared.

Clark's Brake, too, one of the chain-and-lever sort, has long been before the public, favourably looked at, and tried; but has failed to be permanently adopted. At present Mr. Webb, Engineer of the London and North Western Railway, is trying a modification of this apparatus as an emergency brake, to be thrown on by guard or driver on the appearance of danger.

Another brake of this kind, the "Heberlein," from Germany, has recently had a company formed in this country to promote it, but I do not hear much of its progress.

The application of brakes such as these, with metallic connections through a train of carriages, is attended with almost insurmountable difficulties. Of these the longitudinal oscillation is the greatest; but there are also the curves of the line, the swaying of the carriages from side to side, and the jerking generally to which they are subjected; and to all these it is next to impossible to accommodate machinery. I do not mean to say that the "mechanical" brake is exhausted; but I think that even if one be made workable, it will be an affair not only complicated, and therefore costly, but so grating and disagreeable in action to people of a nervous temperament, that it has no chance of being permanently adopted. In this opinion I am borne out, not only by the course of invention, which of late years has been applied almost entirely to realise the "Pneumatic" system, but by writers of admitted authority. I find, for example, the *Railway Gazette*, in 1873, commenting on a pamphlet which it holds in high estimation, and which in treating fully the question of brake power, advocates the use of the Continuous Brake worked by *compressed air;* and in the *Engineer* of the 5th instant there is copied a long report from a Committee of American Engineers, who have been investigating the subject of brakes, and in doing so,

have ignored "mechanical" brakes altogether, and discussed only *air* brakes. To *air* brakes I will therefore now turn.

Some time ago threatenings of prosecution for infringement of patents sent me to the Brake Records of the Patent Office to seek material for defence. It was a question of "air" brakes, and I went back for twenty years to see what could be found; and was astonished to discover, as I daresay many will be astonished to hear, that about that time there were air brakes patented, making as good continuous brakes as those of the present day, which have been so much talked of and lauded. Our recent brake inventors have, in fact, been re-patenting the brakes of a former period; and it strikes me that, had railway directors been as anxious to save the lives of passengers, as they have been intent on competition and speculation, the brake problem might long since have been solved.

I found, as a product of 1857, a very good brake by an inventor called James Harris, who says in his specification—"My improvement consists in working the brakes by compressed air, and is effected by having as prime mover an air pump fixed to the framework of the engine, tender, guard's van, or passenger carriage, and worked by crank or eccentric," &c. The other parts, he says, consist of cylinders, pistons, and levers applied to the brakes of each carriage. The cylinders may be placed on the side, or top, or beneath the seats of the carriages, and he proposes to employ air *at 18 lbs. per square inch compressed to half its bulk.* Mr. Harris does not seem to have been well informed on the question of pressure, but he produces a workable brake, some of the points of which have been incorporated into recent American inventions. He does not, moreover, stand alone in his ignorance or fear of pressure, for many engineers and a leading London journal have declared that I would fail to work a paltry pressure of 70 lbs. on the square inch.

Another eminently workable brake was passed into the Patent Office by two French gentlemen, called Du Trembley and Martin, in July, 1860; and, strange to say, this brake is in all its essential properties the same as Smith's American vacuum brake, now so highly lauded and finding so many admirers—the same as "Smith's" in working the vacuum principle, almost the same in its diaphragm cylinder, and the same as regards its finding a vacuum by the use of an ejector. A moiety of this invention finds its way into one American patent, and the remainder is swallowed wholesale into another.

The third air brake of my series is called M'Innes's Brake, and

is dated October, 1860. This brake, which I promoted, is likewise a perfectly practicable one, containing some good points, and for the first time laying down the idea of the employment of two coupling pipes instead of one only, as suggested by preceding brake patentees. The proper means of coupling is exceedingly important; and any one who has not turned his attention to this subject would be surprised to find how much the success of a brake depended on it. These air-pipe couplings (unless you make mere face plates) must be male and female in character; and if you put what occurs most naturally in practice—viz., the male part of the coupling to one end of the carriage and the female part to the other end—you will see betimes two males or two females presenting, and find yourself under the necessity of turning the carriages bodily round to fit the couplings. A hermaphrodite coupling is about as ill to conceive as the perpetual motion, and the only solution of the difficulty is to have double pipes, so as to have both a male and female part at the ends of each carriage; when, turn the carriages as you will, the pipes will present properly. I consider the *double* pipe as the key to the Pneumatic system, as making connection practicable, and admitting of the use of the "direct" system of braking with one pipe and the "reaction" system by the other.

Passing over a space of ten years with the crudities and commonplaces patented—for nothing new turns up within that time—we come to what may be called the "Brake Agitation" period. Brake engineering had been making rapid strides in America, accelerated by the necessity of getting rid of human labour for working the brakes; and this, along with the movement of American speculators eager to get hold of the British market for the supply of brakes, has brought the subject home to us so forcibly that it has become a national question. But the brake idea has now taken a new form. The "block" system had begun to be introduced on railways, and ideas of a "block" brake have in consequence taken possession of the engineering mind. Within a month of the patenting by Mr. Westinghouse of his "direct-action" brake, I find him in the Patent Office with a "reaction" or "block" brake. Something more than a mere train stopper was found to be wanted, and this invention was for the purpose of bringing up a train which might have gone off the line, or whose carriages had got dislocated. Several inventors, however, as well as Mr. Westinghouse, spring into existence about this time with the "reaction" principle in view.

Mr. Galloway, an Ayrshire gentleman, patented in 1869 an air and spring brake founded on this principle.

A Lieutenant Bolitho, of the Prince of Wales' Dragoon Guards, patented in 1872 a highly ingenious apparatus; and had the lieutenant been as much of a mechanic as he is evidently an engineer, he would have taken precedence of us all; but his machine is needlessly cumbrous, has too many parts to keep in order, and he has used the reaction system only to *take off* his brakes, thus missing the primary point of value in the system.

Mr. Stirling, of the Glasgow and South-Western Railway, in 1873, patented an air and spring brake, after the manner of Mr. Galloway; and immediately after Mr. Stirling, a Mr. Salmon, of London, patented the same principle; but, in short, the air was pregnant with the "reaction" idea, and nothing but a "reaction" brake will now be admitted.

Having thus shewn that in the invention of brakes there has been a gradual development going on after the manner of the Darwinian processes, I now come to direct attention to one of the most recent forms of brake—viz., that with which my own name is associated. The illustrations annexed render description almost needless. I may say, however, at the outset, that it is a "reaction" brake, and nothing but a "reaction" brake. The air required to work the brakes is or may be prepared in the same manner as for the "direct-action" brake—viz., by donkey, eccentric, or direct pump, wherever there may be power. In the locomotive shewn in the illustration, there is a horizontal direct-acting donkey steam engine, with air pump attached. Under the footplate of the locomotive is placed an air reservoir two or three feet in diameter, and say four feet long. From this a pipe leads to a reducing valve attached to a three-way cock, and the pipe making connection with the carriages is seen going round the tender. The air in the reservoir is at a pressure equal to that in the boiler of the engine, but by passing it through the valve it is reduced to 70 lbs. on the square inch before it goes to the carriages. When the lever of the three-way cock is upright the compressed air is on the carriages and the brakes off, and when the lever is turned down the air escapes from the carriages and the brakes go on; that is to say, the normal condition is that of having the compressed air to keep the brakes off, and anything which disturbs this normal condition puts the brakes on. The air gets into and remains in both ends of the carriage cylinders in this normal state of things; in the abnormal state the air is withdrawn or escapes from the upper end of the cylinder only, and the confined air below, five or six times the bulk of that which escapes from above, expands and forces up the piston, the rod of which is

connected by plain links to a bent lever, and through it puts on the brakes. The arms of the lever are as four to one, but may be in any ratio to square with the pressure, size of cylinder, or length of stroke. To assist the reducing valve to keep the pressure on the two sides of the piston in a working balance, the piston rod is enlarged, in order to diminish the piston area below and give predominance to the air power above. This enlargement gives some five square inches of area, which with the weight of piston rod, links, and lever, insures the upper air sending down the piston to take off the brake. Of course, when the air is off above, there is plenty of area and pressure below to lift the piston and put on the brake. The cylinders being outside, the pipes go over the carriages, and the air passes all through the upper ends of the cylinders, to which the couplings are attached; and as there is but one action there are no valves in connection with the system. The air gets into the lower end of the cylinders past the cup leathers, which being in reverse offer little resistance to its passage down. A small check-valve, however, is likewise patented for this purpose. The couplings are of quite a new pattern, attached sideways instead of endways, as is usual, and fulfil several important ends.

To satisfy the railway mind, the brake of the future must act with something like human intelligence: it must be capable of giving signals of distress; it must apply itself when it feels a train going off the rails; and it must be capable of holding in check any unruly carriage wishing to run away. Now, all this my brake can do. I claim for it that, as a train stopper, it is as good as any other brake; that it, further, gives every facility for signalling; that it acts on an incline in the case of carriages breaking away; and that it acts where a carriage goes off the rails, and will stop that carriage and every other carriage of the train as well. Had it been on the train at Shipton no lives would have been lost, as the train could have been stopped twice over, in the time which elapsed between the carriages going off the line and going over the embankment. In speaking of the Kirtlebridge accident, I alluded to the use of a mere train-stopper; in now mentioning the case of Shipton, however, I allude to the *automatic* action of the brake, which it possesses in common with its ordinary stopping power. As for the great accident at Wigan, when the carriages flew about like a flock of wild geese, it is clear that had this brake been on, the carriages could not have slid far on the ballast of the railroad, my own opinion being that 50 to 100 yards would have brought any of them to a stand-still, whereas, unbraked, they ran

300 to 400 yards. Lastly, in the event of a dislocation accident, like that at the Helmshore incline, fourteen and a half years ago, where eleven persons were killed on the spot and one hundred injured, this brake is all sufficient.

EXPLANATION OF PLATES.

Plate I.—Locomotive and Tender.

A. A. A. A., Steam pipe to air-compressing engine. B., Steam cylinder of compressing engine. C., Air cylinder of do. D. D., Air reservoir. E. E. E., Three-way cock and pipe from air reservoir to brake cylinder on the tender. F., Brake cylinder of tender. G. G. G. G., Reducing valve and pipes connecting the reservoir with train, and H., Bracket for attaching flexible tubes from tender to carriages.

Plate II.

Fig. 1. A. A. A., Brake cylinders of carriages. B. B., Links connecting piston rod with bell crank. C. C. C., Bell cranks. D. D. D., Tension rods connecting bell cranks with brake blocks. E. E. E., Brake blocks. F. F. F., Air vessels of brake cylinders. G. G. G., Levers for fixing flexible tubes to sides of brake cylinders. H., Signal fog horn. J., Bracket for attaching fog horn. K. K., Fog horn valve rods. L. L., Brackets, levers, and weights for working fog horn valves. M. M. M. M., Main air pipes connecting brake cylinders. *a. a. a. a.*, Bell-pulls, and *b. b. b. b.*, Cords connecting bell-pulls with fog horn levers.

Fig. 2. A., Brake cylinder. B., Link connecting piston rod with bell crank. D., Triangular tension rod from bell crank to brake blocks. E. E., Brake blocks. G. G., Levers for fixing flexible tubes to sides of brake cylinders. H. H., Signal fog horns. I., Valve box of fog horn. J., Bracket for attaching fog horns to main air pipe, and K., Valve rod for fog horn.

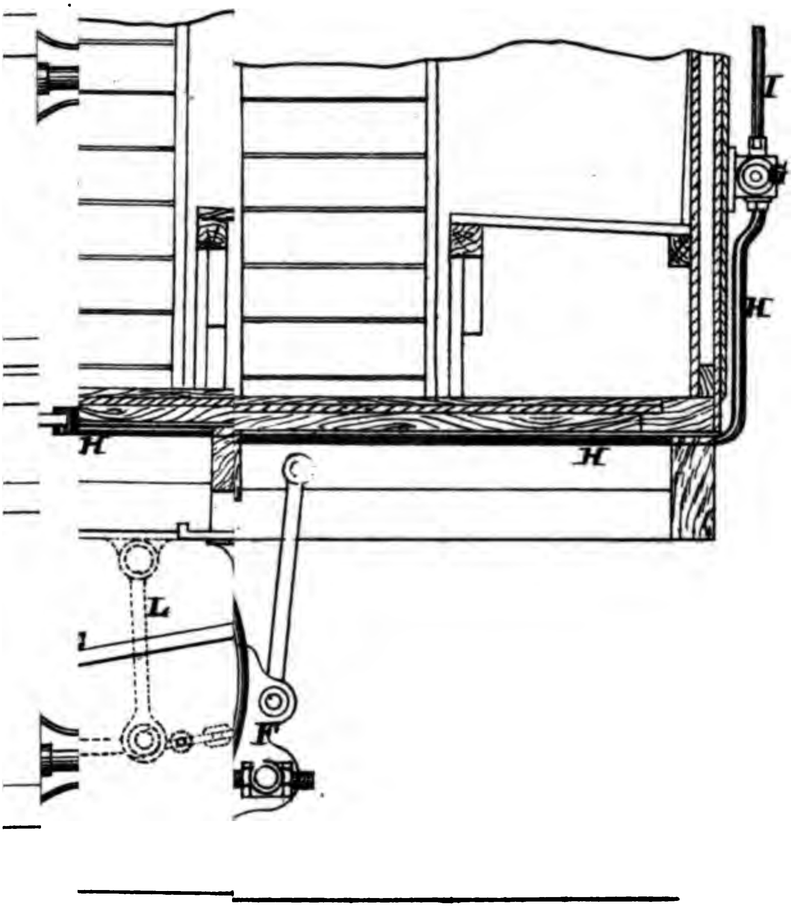
Plate III.

Fig. 3. Plan of carriage frames. C. C., Bell cranks. D. D. D. D., Tension rods connecting bell cranks with brake blocks. E. E. E. E., Brake blocks, and O. O. O. O., Transverse distancing rods betwixt brake blocks.

Fig. 4. Shewing application of cylinder and air vessel in centre of carriage, with rods, &c., for applying brake blocks to wheels. A. A., Brake cylinder. B. B., Air vessel. D. D., Long ends of bell cranks. E. E., Triangular tension rods connecting bell cranks with brake blocks. F. F., Brake blocks. G. G., Brackets for fixing flexible tubes to ends of carriages. H. H. H. H., Main air pipe below carriage frame. I. I., Air pipes to fog horns. J. J., Air pipe to brake cylinder. K., A modification of differential air-valve admitting air to air vessel. L. L., Stay rods, and M. M. M. M. and N. N., shews the application of the funicular motion for applying the brake blocks.

Plate III.

THE '



[illegible] Westinghouse perfected a brake, called the "Westinghouse [illegible]atic Brake," by means of which even more was attained than

PLATE IV.

Figs. 1, 3. Elevation and section of air-compressing engine. A. A., Steam cylinder. B. B., Valve chest of do. C. C. C., Piston of do. D. D., Piston rod for do. and air pump. E. E., Piston for air pump. F. F., Body of air pump. G. G., Piston valve for steam cylinder. H., Steam chest for do. K. K. K. K., Lever and hand rod for moving piston valve. *a. a.*, Adjusting studs for valve. *b. c.*, Cylinder steam ports. *d. d. d. d.*, Steam ports for driving piston valves. *e.*, Exhaust port. *g.*, Covering plate for valve steam port. *h. h.*, Set screws for regulating steam for driving piston valves. *i.*, Steam pipe. *k. k.*, Holding down bolts. *m.*, Lubricator. *n. n*, Condensed steam cocks for cylinders. *o. o. o. o.*, Suction valves for air cylinder. *p. p.*, Discharge valves and pipes for do. *r. r.*, Leading air pipe. *s.*, Retention valve for do. *t. t.*, Air pipe to reservoir. *u.*, Lubricator for air cylinder.

Fig. 5. Plan of air pipe above air pump.

PLATE V.

Fig. 1. Side elevation.

Fig. 2. Front section of brake cylinder and air vessel. A. A., Brake cylinder. B. B., Connecting links to bell cranks. C. C., Bell cranks. D. D. E. E., Coupling ends for flexible pipes. F. F., Air vessel attached to brake cylinders. G. G., Levers for fixing couplings to sides of brake cylinder. L. L., Cast-iron bracket for bell-crank. C. C. M. M., Air pipe to cylinders. N. O. O., Blow-off cock and connecting pipe. P. Q., Differential valve and pipe connecting upper end of cylinder with air vessel. R. R., Cylinder bottom. S. S., Packing gland and cupped leathers.

Fig. 7. Section of differential valve and pipe leading to air vessel.

DISCUSSION ON MR. STEEL'S PAPER.

Dr. J. T. KING, the representative in Europe of the Westinghouse Air-Brake Company, said that the first pneumatic brake had been proposed in the year 1835 in the United States, the next on record being that of Mr. James Nasmyth, of steam-hammer celebrity, in 1844. In 1869 Mr. Westinghouse perfected and put into use his air brake, which was now at work on between three and four thousand locomotives and cars, equivalent to twenty thousand British passenger carriages. That brake, he confidently affirmed, did everything that Mr. Steel proposed to do, except that it did not automatically apply itself in the event of a carriage-coupling breaking, or in the event of a carriage leaving the line. But in 1871 Mr. Westinghouse perfected a brake, called the "Westinghouse Automatic Brake," by means of which even more was attained than

Mr. Steel proposed; for, in the event of a passenger desiring to have the train stopped, he had only to pull a cord and a whistle was thereby caused to sound close to the ears of both driver and guards. This brake had now been in use for some time on hundreds of carriages. The difficulty, which had been alluded to, of keeping the stuffing glands tight, was avoided in it by using instead a triple valve, which acted with the most perfect certainty. As regards the coupling pipe, the Westinghouse brake would also compare favourably with Mr. Steel's; for, in the case of a carriage-coupling snapping, the Westinghouse coupling pipe would simply slip apart without hurt, and be ready for use again.

Mr. M'Gavin said that there were many railway directors into whose brains it took a long time to inject any new invention; but there was this to be said in their defence, that so many inventions were put before them, that they became of necessity cautious and sceptical. With such a brake as had been described many accidents would be avoided.

Mr. Day, in answer to Mr. M'Gavin, explained that the air-brake did not interfere with the use of the ordinary brake, either on the tender or behind.

Mr. Deas said that if the fittings of the brake would bear a reasonable working strain, it appeared to him that Mr. Steel had really supplied a desideratum. The Westinghouse brake had been a long time before the public, and it was surprising that it had not been more generally adopted, provided it was the thing wanted. The Government, however, ought, in the interest of the travelling public, to take up the question of brake power, decide which was the best brake, and have it universally adopted. The Philosophical Society might do good work in memorialising the Government to appoint a Commission for this purpose.

Dr. King handed in a copy of the *Proceedings of the Franklin Institute*, April, 1874, containing an account of the Westinghouse Automatic Brake, with experiments by a Committee of that Institution.

Mr. Day drew attention to the question of cost, and said that if the details of the Westinghouse were compared with those of Mr. Steel's brake, any engineer would pronounce that the latter would cost much less than the former.

Dr. King, in answer to Mr. Dron, explained more fully than

ı the character of the coupling pipe in the Westinghouse
a.

STEEL, in closing the discussion, pointed out that he had
ɘd before to state that with his brake not only had passengers
›wer of signalling to the officials in charge of the train, but
ıad also the power of applying the brake in cases of emergency
ıatter frequently of great importance, as was shewn in the case
Shipton accident.

XXVI.—*Discussion on Mr. Andrew Crawford's Waste-Preventing Water-Supply Apparatus.*

[Paper * read, 10th March; Discussion held, 14th April, 1875.]

Mr. James R. Napier said that Mr. Philip Henry Holland had some years ago proposed a similar plan for saving water and reducing the cost of the water fittings; he used very small supply-pipes leading through the house into air vessels, with a large three-way delivery tap. Mr. Crawford's delivery valve appeared to be novel, as it would no doubt prove to be effective. If the Corporation of the City of Glasgow were really in earnest in their desire to save water, it was surprising that they did not see that the simplest of all means, as well as a most effective, was to restrict the quantity of supply at the main itself to the amount paid for, and so make it impossible for any one to get more than he was entitled to. If the consumer got this quantity, he might surely be allowed to use it or waste it as he pleased. It would be the consumer's interest then, and not the Corporation's, to see that his taps and fittings were tight. A truncated cone, having a diameter of one-tenth of an inch at the main, and widening into a pipe of about half an inch diameter, would at the ordinary pressure supply the biggest family in Glasgow. The greatest quantity which could be run by it would be about one gallon per minute. With such a restricted rate of supply, or even with a considerably larger rate, the consumer would find himself compelled to adopt cisterns of some kind; and probably the most economical and best are such close ones as Mr. Holland and Mr. Crawford have proposed, where a limited quantity, depending on the size, can be drawn off periodically fresh and pure from the main as rapidly as may be desired. The saving of one-half or three-fourths of the whole water at present supplied to the city, which such a system would effect, would greatly reduce its cost to the consumer, and far more than pay for the cost of close cisterns with Crawford's or other suitable valve.

In Mr. Crawford's application to water-closets there is absolutely

* The paper is No. XX. of the present volume.

no waste. But until the supply is restricted, or consumers have to pay for what they use and waste, we are not likely to have cheaper water or less waste.

Mr. M'ADAM said that the principal cause of the waste of water in Glasgow was the present water-closet system. This had been conclusively proved in the following way, shortly after the system was introduced:—The quantity of water flowing through a certain main at 2 P.M. was first measured, and then the quantity flowing through the same main at 2 A.M.; and it was found that, instead of the flow at the early hour being inconsiderable, it in reality amounted to two-thirds of the flow at the other hour. The cause of this was ascertained to be defective arrangements connected with the ball-cocks of the cisterns in the water-closets; for many of these cocks were actually found out of order; and by employing a number of men to examine and repair them, the waste was appreciably diminished. There was little doubt that at the moment of speaking several thousands of them in the city were not in good order, and that much water was being thereby lost. At present, however, this could not be viewed as pure waste, for the supply was plentiful, and what escaped doubtless served a good purpose in connection with the sewage. The level of Loch Katrine had been raised about four feet, and they had the power to depress it three feet, so that there was a depth of seven feet to work upon. Now, as a matter of fact, with all the waste spoken of, the level had never been lowered more than eighteen inches. He was glad, however, to see such an apparatus as Mr. Crawford had exhibited.

Councillor JOHN TAYLOR, jun., mentioned that an experiment had recently been made to test the cause of waste in one of the suburbs of the city, where there were somewhat over two hundred houses; the average number of taps in each house being 18½, and the average number of inhabitants seven. The quantity of water consumed at the first examination was at the rate of 59 gallons per head per day. An inspector then went round to examine the taps and ball-cocks, many of which were found out of order, and were in the course of a fortnight repaired. The consumption was, thereupon, ascertained to be reduced to 35 or 36 gallons per head per day, and in the course of six weeks or two months it was further lowered to 25 gallons per head per day. This went far to shew that the best means of preventing waste would be to see that the fittings of the plumber-work were in proper order, and that servants were strictly cautioned on the subject by the head of each house.

Mr. W. R. W. Smith agreed that the waste due to defective fittings was large, but from experience he despaired of getting this remedied. He could count *thirty* possible places of waste in his own house.

Mr. Scott pointed out that another source of waste was the quite excusable custom which some people had, whose water-closet cisterns were connected with the usual water supply, of running off every morning the whole water of the cistern. The necessity for an apparatus like Mr. Crawford's might come sooner than the mere scarcity of water would demand, if the idea were entertained of a limited supply in connection with the treatment of sewage.

Mr. James Smith said that five years ago, when the water question was so vigorously discussed in Edinburgh, the plan of Mr. Napier was much written about, but for some reason or other was not adopted. Were it introduced there would be fewer defective fittings, for if the supply were limited it would be every householder's interest to see that they were in proper order.

Councillor Dron said that the Corporation were at present considering a scheme for bringing in water from the neighbourhood of Eaglesham at a cost of £360,000 or £380,000. This would cause a very heavy demand upon the public purse; whereas if Mr. Crawford's water-closet were adopted in Glasgow, they would, without doubt, save 25 or 30 per cent. of the water at present being lost. The only possible place of waste in Mr. Crawford's apparatus was at the india-rubber rings, and these could be renewed at any time. The present style of water-fittings were a disgrace to the plumbers of Glasgow, being defective in both workmanship and material. The time was coming when the Corporation would require to have the workmanship done to a standard, and passed by their own engineers. He had seen Mr. Crawford's closet in action in various places, and had been highly delighted with all the component parts of it. He wished it were introduced not only in Glasgow, but wherever water-closets were in use. It was to be hoped that the Water Commissioners would give it their careful attention.

Mr. Bromhead entirely dissented from Mr. Dron's view, and thought that if money was to be spent at all, it should be spent in obtaining a greater supply of water.

Dr. WALLACE said that as it was preferable to obtain the water for kitchen purposes direct from the mains, it would be better to restrict the apparatus under discussion to the water-closets. The pipes of new houses in Glasgow should, he thought, be so fitted as to be prepared for the great pressure of the Loch Katrine water.

Mr. CRAWFORD, in closing the discussion, said that in regard to the cost of cisterns there was a slight misconception, some members thinking that the Corporation was expected to be at the necessary expense. As a matter of fact, however, every closet was required at present to be supplied with a cistern fitted up at the expense of the proprietor, and the apparatus shewn was only to be in the place of those cisterns in new buildings in which this system is adopted. If introduced it would do away with the ball-cock, overflow pipes, and a great many other fittings, and would curtail the plumber-work to a great extent. The price of it was less than the cheapest of the contrivances at present in use, being 25s. for a cistern and valve for 2 gallons. Contamination of the water needed not to be feared, as it was to a great extent to prevent this that the contrivance had been made. No dust could get in, and the vessel itself, being made of iron, could not injuriously affect the water. The Commissioners had allowed six of the water-closets to be fitted up about six months ago, during the frost; and when others in the locality were a great source of annoyance, these had never been touched.

XXVII.—*On the High Antiquity of Iron and Steel.* By Mr. St. John Vincent Day, Assoc. Inst. C.E., F.R.S.E., &c.

[Read before the Society, April 26, 1875.]

In some previous communications to this Society * dealing with questions bearing upon the extremely archaic use of Iron and Steel, I ventured to bring together and discussed a variety of evidence in proof of the claims for Iron to be considered amongst the earliest, if not the very earliest of materials used by the human race, and that not in more or less recent periods, but notably that Iron was largely used in the most distant ages which we can with certainty fathom. Those claims the evidence, when candidly sifted, clearly asserts to be much stronger than what the archæologists had previously held; so strong, indeed, as to negative the popular and too hastily drawn conclusion, that man did not commence to use Iron until after whole millenniums of dealing with Bone, Stone, and Bronze.

The conclusions which I formerly gave expression to as having reached, from a re-sifting of the evidence, and also from having had further and more direct evidence to discuss, than, so far as I can gather, came under review of any of my predecessors in this particular field of research, although directly opposed to the views up to that time generally accepted, are now admitted by Egyptologists and those metallurgists who, having a safe foundation in the principles of a more or less exact science, have, of all persons who have approached questions bearing on the metallurgy of the ancients, and not bowing down to any particular theory, alone been able to deal with it in the spirit of a thorough understanding of certain essential conditions involved, and by correlating which is it alone possible that the Truth can be reached.

It would take far more time than we have now at our disposal to deal with this subject in that complete manner which it so well

* Vide *Proceedings*, vol. vii., p. 476-488, and vol. viii., p. 235-268.

deserves, still more would it take to deal with all that other evidence which has with such surprising rapidity grown together, plainly indicating that in the East—whether it be among Semitic, Aryan, Hamitic, Sporadic, or Allophyllian races—the further back we reach, by so much do we receive proofs in the most ancient times of people endowed with a high practical acquaintance with the use of metals, and Iron, in particular, in its various forms of Malleable metal, Cast Iron, and Steel, prevailing and holding rule; we find, in fact, not a progressive rise in the qualities of materials used by man—that is to say, from those which are more or less soft and yielding, upwards to those which are necessarily harder and unyielding, still less for a time do we find a progressive retrogression; but what we in strict reality do reach as the ultimate outcome of our inquiry is an age in which a high civilisation, not a civilisation produced by culture, indeed, so much as a civilisation due to natural, innate insight, rules—in which, to return once again to our immediate subject, all the metals, both noble as well as ignoble, precious stones and woods, are all together not only in full employment by the men of the time, but the very names for which are common words in all the oldest forms of language, whether in Egypt, Babylonia, Assyria, India, or even China. (See Table at the end.) The theory of a gradual transition by man in the use of substances progressively ascending from those which are comparatively soft and requiring but little skill to fashion to his necessities, up to those which are hard and unyielding and apparently needing a higher skill to utilise them, has in fact no foundation in those countries which were admittedly the earliest peopled; it is, in short, a conclusion which has been evoked in North-West Europe from researches for the most part dealing with evidence belonging to the Christian Era; and by virtue of those belonging to so comparatively recent an age, the inferences drawn are necessarily from a partial testimony, and therefore cannot be considered reliable.

But as is always the case in the pursuit of any subject outside the pale of pure mathematics, our first formed conclusions subsequently undergo modification, especially if founded upon what we had supposed at the time to be a complete array of facts, but which has later on received additions and perhaps correction; so in the present case, I am desirous to acknowledge and to correct some instances, not so much perhaps of actually wrong conclusions, but such as were fore-shortened and imperfect, at the same time to adduce further evidence which I have since collected, and which clenches as with an unyielding grasp, the arguments I formerly ventured to propound.

Yet before saying more, and in order to compress what I have now to add into the least space, and to make it as easily applicable to the former papers as possible, I shall follow, so far as practicable, the order in which the subject was treated of in them, by dealing with the earliest populated countries first, and then following the peopling wave as it spread in other countries, so far as our knowledge thereof will permit.

We will first, then, go back to Egypt.

EGYPT.

The difficulties in the way of deciding whether Iron was known to the Proto-Egyptians—to the men who erected in that country the earliest and most stupendous edifices of any age, and which they continued to erect, but always in a retrograding order, so far as dimensions and excellence of workmanship are concerned, from the Delta southwards, for about 1600 years—were insuperable, until in the first place Colonel Howard Vyse's Engineers removed by blasting from the oldest and largest building there, nay, in the entire world rather, the piece of Iron now in the British Museum, and which is illustrated by a plate in the seventh volume of this Society's *Proceedings;* and in the second place, the reading of the hieroglyphs became so far advanced, that it enabled the mention of that metal to be detected in some inscriptions belonging to the third dynasty of Memphis, to which I shall presently refer. Since the occasion, when, nearly four years ago, I directed the attention of this Society to the existence of this very unique specimen of some primeval Oriental smith's handiwork, there have not been wanting those who have raised certain doubts respecting it, and these based partly on the difficulty of accounting for a sufficiently actual Egyptian source of Iron ore to produce the metal in the quantity in which it must have been required, if it is once granted that the early Egyptians knew of Iron or even used it at all. I had certainly from the first held this difficulty in full view, and never felt satisfied regarding it until ascertaining* the existence of Iron in the Egyptian limestone, and the manner in which it accumulates in fissures, as set forth in my second paper. (Vide *Proceedings,* vol. viii., Dec. 4, 1872.) Yet that answer to the difficulty, whilst deemed satisfactory at the time, sinks into insignificance when placed against the immensely extended and incontrovertible proof since brought to light by Mr. Hartland.

* From information kindly furnished by the Astronomer-Royal for Scotland.

It is many years since Mr. Francis Galton found a black-looking slag in some exceedingly ancient Sinaitic remains, conjectured to be anterior to the time of Moses;* but it is only quite the other day that the import of this first step in a discovery received its due weight, and was consummated by the further finding of vast Iron-works by Mr. Hartland, in the neighbourhood of that part of the Sinaitic peninsula which was held in subjugation by the kings of the third and fourth dynasties of the old empire reigning at Memphis, as proven by the monumental tablets in the Wady Meghara.

To this discovery I shall presently recur; but before dwelling upon it, it is important to shew that the prior discoveries of the mention of Iron in some of the earliest hieroglyphic tablets left it more or less probable that such allusions or references as are found in these lithic writings might at some future time be corroborated by the discovery of relics of the actual Egyptian Iron manufacture; and on the other hand, the finding of such remains is proof again that the hieroglyphic readings, even with the halos of uncertainty which in respect of the metals have until quite lately surrounded them, and which have been so fully acknowledged by Lepsius,† are, if not precisely so, at least very approximately correct.

At page 487, vol. vii. of the *Proceedings,* I mentioned that the oldest known Egyptian word for Iron in one of the dialects was Benipe; in another dialect the initial B is commuted to P, and the word becomes Penipe, as I have been since informed by Lepsius.

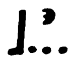
On turning to the *Dictionary of Hieroglyphs* we find, without an explanation, however, being given, by which an intelligible view of the position may be gathered, all the annexed hieroglyphs, with the phonetic values marked for this one substance, in the order in which they are here set down. (See Table on next page.)

Evidently, then, assuming for the moment that the phonetic values are correct as given by Dr. Birch, it may be said that Ba is a constant in those phonetic values which have been assigned to hieroglyphs translated as Iron; but this is a point leading into the most subtle intricacies of the science of language when truly and genuinely followed, the Egyptian *ba* corresponding, I am strongly inclined to believe, to what we find in the χαλκός of Homer, to which an exact value is frequently given by the coupling of an adjective, such as ἐρυθρός, red; αἴθοψ, black, &c.

* Percy's *Metallurgy,* 1st edition, page 874.

† *Die Metalle in den Ægyptischen Inschriften,* Von C. R. Lepsius, aus den Abhandlungen der Königl. Akademie der Wissenschaften zu Berlin, 1872.

TABLE.

Hieroglyphs.	Phonetic Value.	Translation.
	Ba.	Earth, Metal.
	Ba.	Iron.
	Baá.	Iron, Earth.
	Baáenepe.	Iron.
	Bet.	Iron.

Indeed, this view has been strengthened from a recent conversation with Dr. Birch, in which he informed me that, agreeing with Lepsius, the rendering or phonetic value of the hieroglyphic symbols for Iron is still very uncertain. On November 6th, 1874, when at the British Museum, Dr. Birch expressed to me his belief that the first syllable Ba was a general term, signifying metal, and a particular metal was denoted by the use of prefixes signifying its qualities, such as white, black, yellow, &c.

Whilst, then, in the Sahidic dialect, which is said to be the oldest, we have the word *B*enipe, and in another Egyptian dialect *P*enipe stands for Iron, or the initial B and P are commutable; this change corresponds to what we find in the Hebraic and Chaldee tongues, where in the former we have *B*arzel, in the latter *P*arzel.

Again, with further reference to the old Egyptian word for "Iron," it appears to have been proved, according to another statement by the Rev. Basil H. Cooper,* that the sixth successor of Menes, or the seventh king of Egypt, bore in the royal oval or cartouche containing his name the very word "Benipe." His name was "Mibampes."

"Nine years ago," says the Rev. Mr. Cooper, "the name of this monarch was only known from Manetho and Eratosthenes, in both of whose lists of kings it appears in a more or less corrupted form.

* *Antiquity of the Use of Metals, especially Iron, among the Egyptians*, page 18. Reprinted from the *Transactions of the Devonshire Association for the Advancement of Science*, &c., 1868.

The royal oval or cartouche of this king does not appear in the tablet of Karnak, nor on the old tablet of Abydos, nor has it been detected on any isolated monument; but towards the end of 1864, when the tablets of Saqquara near ancient Memphis, and the new tablet of Abydos were published—the former having been discovered by Mariette Bey, and the latter by Herr Dummichen—this 'Iron King's' name was brought to light."

"On the tablet of Saqquara, or Memphis, which, like the old tablet of Abydos, belongs to the reign of Rameses the Great, say about the thirteenth century before the Christian era, the Iron King is actually the first of the fifty-six ancestors of Sesostris, whom the tablet originally comprised, and nearly all of whose escutcheons are still very well preserved. In the new Abydos tablet he stands sixth, one king being omitted in the interval, as we learn from the invaluable Hieratic Canon of the Pharaohs preserved in the Turin Museum, in which priceless document the discovery of the new tablets at once enabled Egyptologists easily to spell out the name, which had previously been undecipherable. In all the three hieroglyphical records the name reads distinctly, 'Lover of Iron'—of course meaning, 'Lover of the Sword'*—thus attesting not only the extreme antiquity of the use of Iron, but unfortunately also of that most dreadful evil of all which are the scourges of humanity, war."

But the evidence on behalf of early Iron-working in Egypt does not terminate with the mention thereof in the Inscriptions.

We will now consider the important discoveries of Mr. Hartland, already alluded to. In the early part of 1873 Mr. Hartland described to the Society of Antiquaries his visit to Ayûn Mûsa (the Wells of Moses), by the Red Sea, the Wilderness of Sin, the lonely march of three days across the parched desert to the palm-tree groves of Wady Gherundel, and the defiles leading to Sinai. Mr. Hartland has built a house, in order to carry on his researches, near the junction of the Wady Kemeh, the Wady Mukattab, or the Written Valley and the Wady Meghara, and having taken some of

* This may possibly be one and a true rendering of the title, "Lover of Iron," but that it is the whole meaning involved under it, I think, may be seriously questioned, for we must remember that all art, and especially architecture, or the expression in material form or by sculptured symbol of all that was highest and deepest in man, could not receive such expression in well dressed and accurately finished stone, until the material for furnishing instruments for acting thereon was acquired; so that it is clear King Mibampes may well have been a "Lover of Iron," without necessarily being a warrior. —St. J. V. D.

the friendly tribes into his pay, has succeeded in discovering the old turquoise mines of the ancient Egyptians, the rocks that they worked for these stones, and it is said the very tools they used. also the places where they ground and polished these stones. This, however, is incidental, and but leading up to the other discovery, which is of so much importance to the subject of this paper; for. whilst investigating in other directions, Mr. Hartland has come upon the remains of Ironworks. These works stand adjacent to the mines on some hills, at a place called Surabit-el-Khadur, and were constructed on the Catalan system, in the opinion of their discoverer. The ore was very imperfectly extracted—slag brought over to this country, from the immense heaps that like mountains are piled around, contains as much as fifty-three per cent. of Iron. These works were commenced in very early times; each Pharaoh. as he continued them, added a large engraved stone, not unlike our tombstones, to state his work.* "It is to be hoped," remarks the author of the paper describing this unique discovery, "that rubbings of these stones may be sent to some of our skilled readers of hieroglyphs, since much valuable historical information respecting the Egyptian metallurgy may have been by them preserved for our enlightenment, and to shew how little the mind of civilised man has developed during 3000 years."

It is further explained by the writer from whom we have quoted the preceding passage, that the district where this unique discovery has been made "has remained unexplored, probably on account of its being off the beaten track; and in an unknown country there is no temptation to stray, particularly as the guides and dragomen discourage any explorations which may add to the risk of the journey."

Besides the ruins of these works and the enormous slag heaps near them, there also exist the ruins of a temple and barracks for soldiers to protect them.

Yet what is more remarkable still, as opposing the modern North European theory of the succession of Stone, Bronze, and Iron ages, is the solid fact that in this temple at the Sinaitic Ironworks, Mr. Hartland found Flint Arrow-heads, which he has presented to the Society of Antiquaries, and which he describes as being the earliest known specimens in the world. It is, of course, possible that the discovery of Flint Arrow-heads side by side with Iron is a mere coincidence, and that the two may be of a different age; but if a mere coincidence, it is not possible, under the circumstances of their

* Vide *Proceedings, Soc. Antiq.*, Vol. v., 2nd Series, June, 1873.

being found not buried deep down in the earth, but in or among the very ruins of the barracks, that they are older than the barracks or Ironworks themselves: they may be coeval therewith, but it is not impossible, nay, it is extremely probable that they are relics belonging to some long subsequent age (in which, as we know to be the fact, the Egyptians had retrograded from their lofty initial standard of excellence in mechanical art), or that they may belong to some inferior foreign race who settled in or swept over the peninsula in a later period. The latter view has a strong probability of being true; for, as we learn from Dr. Schliemann's researches into the mound of Hissarlik,* whether that be the veritable site of the Ilion of Homer or not, the fact is undoubted, that whatever the ruins there covered may be, he finds four cities successively buried and built on one another, and in all of them Flint and Stone implements side by side with Copper, Bronze, and oxidised Iron in abundance; and notably in the fourth uppermost or most recent stratum, where the Flint implements are most abundant, they are there associated with what his English editor describes as primitive wooden buildings, not found in the lower ruins, where everything, and especially architecture, teems with excellence. With respect to Iron in the Hissarlik remains, Schliemann rather significantly remarks—"The only objects of Iron which I found," excepting the sling bullets in the lower stratum, which have been analysed by M. Damour, "were a key of curious shape, and a few arrows and nails close to the surface. From Homer, we know that the Trojans also possessed Iron as well as the metal which he calls κύανος, and which, even in antiquity, was translated by χάλυψ (Steel)." Steel, however, he does not appear to have found; yet Dr. Schliemann adds, "Articles of Steel may have existed. I believe positively that they did exist; but they have vanished without leaving a trace of their existence; for, as we know, Iron and Steel become decomposed much more readily than Copper"—in respect of all which the editor of the English translation, Philip Smith, with a salutary and gratifying warning, adds—"Such facts as these furnish a caution against the too hasty application of the theory of the ages of Stone, Bronze, and Iron;" and whilst I have made mention of the Hissarlik finds as representing almost, if not quite, a parallel to the association of Flint knives with the Sinaitic Ironworks, I have done so with the view of fairly interrogating every side of the question, so that others may discuss it at once from each point of view; yet I think that the weight of evidence will be allowed as decidedly in favour

* *Troy and its Remains.* By Dr. Henry Schliemann. London, 1875.

of the conclusion expressed by Mr. Hartland, that the Flint implements of the Sinaitic Ironworks are the oldest relics of the kind yet found; and in the light of all circumstances involved, the probability is, that they are as old as the Ironworks also, so that in any view of the case we have Ironworks at least as ancient as the Flint Arrowheads, and probably much more ancient. In this connexion, I may further remind you that the Abbé Richard has pointed out the discovery of Flint implements in Egypt, Mount Sinai, Galgala, and in the tomb of Joshua* at Timnath-Serah in Mount Ephraim, from which it would seem almost certain that the Hebrew race, both when in their wanderings in these lands, and after crossing the Jordan, who we know were familiar with the use of Iron, also used implements of Flint; therefore, as the Sinaitic Ironworks now discovered lay right in their track, the Flint Arrowheads brought home

* Paper read before the British Association in Edinburgh, 1871, and in respect of which it may prove useful to quote the following from a recent French work, *La Terre*, by M. Pozzy:—

"'Ce fut au pied du Sinaï biblique, dit-il, que je trouvai le plus grand des ateliers de silex que j'aie encore vu, avec les spécimens les plus remarquables et surtout des pointes de flèches extrêmement fines. La plus jolie a été trouvée dans l'Ouadi Féron, au centre même des montagnes sinaïtiques.

"'Vinrent ensuite plusieurs instruments trouvés en Palestine, à Elbireh, à Tibériade; et entre le mont Thabor et le lac de Tibériade, sur un plateau élevé de plus de 250 mètres au-dessus du Jourdain, dans un champ cultivé, une hache semblable, quant à la nature du silex et à sa forme, à celles de la Somme.

"'Mais les instruments qui méritent, je pense, la plus grande attention sont ceux que j'ai trouvés sur le bord du Jourdain, à Galgal, lieu où, d'après la Bible, Josué reçut l'ordre de Dieu de circoncire le peuple d'Israël, et dans le tombeau que la science archéologique regarde aujourd'hui comme le tombeau de Josué. J'ai trouvé ces instruments soit dans le tombeau même de Josué, dans la chambre sépulcrale intérieure, soit dans le vestibule, mêlés à des débris de poteries, à de la terre, etc.

"'J'en ai trouvé aussi dans le champ qui est devant le tombeau et jusque sous un grand chêne vert éloigné de la tombe de Josué d'environ 70 à 80 mètres; ils avaient éte ainsi disséminés, quand on a fouillé et violé le tombeau.

"'C'est la forme communément appelée *couteaux* qui domine dans ces instruments; quelques-uns, comme on peut s'en convaincre, sont encore très-tranchants. Il y a cependent des scies, des pièces plates et arrondies, etc. La plupart sont du silex; il y en a aussi en calcaire blanchâtre qui semble avoir passé au feu.

"'J'ai l'espoir, continue M. l'abbé Richard, que ces *instruments du tombeau de Josué* et ceux dont j'ai parlé d'abord intéresseront les amateurs si nombreux et si éclairés de l'archéologie humaine que l'Association compte dans son sein; et en les soumettant à votre appréciation, je viens vous apporter non pas des idées préconçues, non pas des théories, mais des faits, de simples faits historiques et archéologiques.

"'C'est un fait historique que la fabrication de couteaux de pierre pour la circoncision des enfants d'Israël à Galgal, non loin du Jourdain. C'est un fait historique que le tombeau de Josué, élevé non loin de Sichem, longtemps oublié

by Mr. Hartland, it is pretty nearly certain that if they belong to a later date than the works themselves, are relics of the forty years wanderings of the chosen race.

To return. Far, indeed, is it from my wish to influence an over-estimate of the importance of this the latest of Egyptian "finds;" but it seems to me very necessary, indeed, to point out that the discoverer, and those who have already written on the discovery, place the age of these Ironworks at too low a date, and for this reason, that they happen to be in the actual neighbourhood in which have been found monuments at least contemporary with and by some computed to be older than the oldest of the pyramids —certainly as old as the fourth, if not the third dynasty of Memphis.

ou perdu, a été retrouvé, et que ses restes ont été vus et décrits par MM. de Saulcy, Guérin, etc. C'est un fait historique attesté par la version authentique des Septante qu'un certain nombre de couteaux de pierre de Galgal ont été projetés dans le tombeau de Josué, au moment de sa sépulture.

"'M. de Saulcy, dans son *Voyage en Palestine*, n'avait pas hésité à dire, dans sa confiance absolue au récit des Livres saints, que ces couteaux de pierre devaient exister encore dans le tombeau retrouvé de Josué. Mais l'abbé Moigno, mon illustre ami, dans son journal *les Mondes*, avait rappelé l'affirmation de M. de Saulcy, et m'avait vivement pressé d'aller, pendant que j'étais en Palestine chercher ces silex. J'y suis allé et je les ai trouvés.

"'Quant aux conclusions que l'on peut tirer de mes instruments, aux arguments qu'ils peuvent apporter ou aux objections qu'ils fourniront contre les théories mises en avant par les diverses écoles anthropologiques ou biologiques modernes, je les laisse de côté.

"'Si mes silex historiques ressemblent à s'y méprendre, par leur nature et leur forme, aux silex que l'on veut être essentiellement *préhistoriques*, je pourrai le regretter, au point de vue des illusions que cette coïncidence peut faire évanouir, mais la vraie science doit accepter les faits, et reconnaître l'identité des silex *préhistoriques* et des silex *historiques*.'

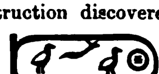
"Le 29 du même mois, M. l'abbé Richard présentait ses silex à l'Académie des sciences de Paris, et dans un compte rendu de cette séance paru au *Moniteur universel* les mêmes faits ci-dessus relatés étaient reproduits.

"De ces faits il résulte, comme nous le disions tantôt, *que les âges de la pierre, du bronze et du fer n'ont pas toujours été successifs, mais quelquefois simultanés.* Il n'est pas douteux par exemple qu' à l'epoque où l'officine de silex taillés était en grande activité, au pied du Sinaï, l'usage du fer était depuis longtemps connu en Egypte. Quand, au pied de ce Sinaï, Dieu menace les enfants d'Israël, en distant: 'Si vous ne m'écoutez point, je ferai que le ciel sera pour vous comme de fer, et votre terre comme d'airain' (Lév. xxvi. 19), qui peut douter que l'usage du fer et de l'airain ne fût connu des Israélites? Quand, après une victorie sur les Madianites, Moïse dit que 'l'or, l'argent, l'airain, le fer, l'étain, le plomb . . . , soint purifiés par le feu' (Nomb. xxxi. 22); quand le livre de Josué parle des chariots de fer des Cananéens (Josué xvii. 16), n'est-il pas évident qu'on connaiséait alors tous ces métaux? Quand, vers la même époque, Job nous dit 'que le fer se tire de la terre' (Job xxviii. 2); quand il s'écrie: 'Plût à Dieu que mes discours fussent gravés avec une touche de fer et avec du plomb, et qu'ils fussent taillés sur une pierre de roche à perpétuité!' (Job xix. 24) ne sommes-nous pas autorisé à tirer la même conclusion?"

I allude to the celebrated Wady Meghara tablets * of the third and fourth dynasties; whence it may be inferred as most probable that we are not far off from, if not actually at, the very source of the Iron and Steel from which the tools were formed to hew and dress the mighty stones of old Egypt's mightiest and oldest monuments. Nay, and until some one shall prove to the contrary, that we have reached the actual forge whereat some primeval smith wrought that one alone known relic of pre-historic Iron-working which has descended to us—itself happily preserved in the treasure-chest of the Anglo-Saxon nation, the British Museum, and amongst all the contents of which there is nothing else which, when followed out *à fond* is capable of teaching a lesson so real, so contrasting—shall we say there is nothing else so *iron*ically vocal from the ages of the old world?

There are, moreover, other facts which seem to render it certain that the foregoing inferences represent the true state of the case, and to which I now direct attention.

No fact is better known than that oft-repeated one, that the oldest architectural monuments in the world are the pyramids and tombs of Ghizeh. Another fact is equally well known, that the question as to how or by what instruments the not only large but intensely hard stones of some of these works were quarried, cut, and dressed into shape, with the exquisite finish we find them possessing in many cases, even now, has never been solved. There are no remains of Ironworks in the neighbourhood of Memphis or Ghizeh, nor in any part of Egypt, nor in the Sinaitic peninsula as yet discovered, other than those we have already alluded to in the neighbourhood of the Wady Meghara. From the tablets in this remarkable valley, we find undoubted evidence of a king of the third dynasty of Memphis at war with and subduing the inhabitants in the Eastern frontier of Egypt. His name was Sephuris, and in the lists of Manetho he is the eighth king of the third dynasty, and the very earliest monarch respecting whom we possess contemporary evidence. His name, Fig. 1, occurs in an inscription

* The cartouches of the same kings are found in the rock tablets of Wady Meghara, as well as in the chambers of construction discovered by Colonel Howard Vyse in the Great Pyramid—namely,  Shofo, and  nu-Shofo - and this fact is strong evidence of their contemporaneousness.

over the doorway of a tomb at Ghizeh, which, the inscription tells us, is that of his own son, whose death occurred in the lifetime of his father. This same name occurs again on a rock tablet in the Wady Meghara, as shewn at Fig. 2, which is a copy from Lepsius. Sephuris is here accompanied, says Osburn, "by his standard or title, *i.e.*, the great Horus (*Aroeris*), lord of justice." . . . . "It seems to have been a war flag. The rock-inscribed tablet whence we have extracted it represents Sephuris holding a foreigner by the hair, and in the act of smiting him with a club or mace. He is called 'SEPHURIS, the great god, the subduer, conqueror of countries.' Like many of his followers, Sephuris was called upon to defend the Eastern frontier of Egypt against foreign aggression. He first recorded his successes on the rocks of this desolate valley, and they have followed his example." *

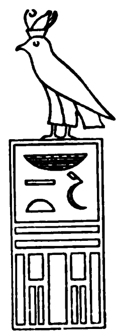


Fig. 1.

Let us observe, that, as belonging to the time before which Sephuris had vanquished his Eastern foes, Egypt has not yielded a certain trace of a single contemporary monument of any kind; that before his time all is traditional *and absolutely devoid of collateral support,* although we believe that it has been thought by some that the mention of Aches, the seventh king of the third dynasty, in a tomb at Abooseer, and which Rosellini also found in another tomb at Saqquara, render it probable that these may be a little older than the reign of Sephuris; but even allowing this full weight, it is trifling and unimportant in comparison with what we find occurring at Memphis after the conquests of Sephuris in countries to the east of Egypt.

The oldest inscriptions are those in the Wady Meghara, in the very neighbourhood where the ruins of vast Ironworks have now been discovered by Mr. Hartland; and is it surprising, then, or rather is it not exactly what we should expect on *à priori* grounds, that there are no inscriptions nor monuments to be found until we come to the very time in which and the site whereat the gravers, the chisels, and other instruments necessary to the inscribing and otherwise working in stone were manufactured, these being even depicted on the very oldest tablets (see Figs. 2 and 4 especially), and that so soon, immediately, in fact, that we find a source for such tools, then we find the rock inscriptions and built monuments produced by their aid in abundance, extending thence through all the active period of Egyptian history?

* *Monumental History of Egypt,* Vol. i., 254-5.

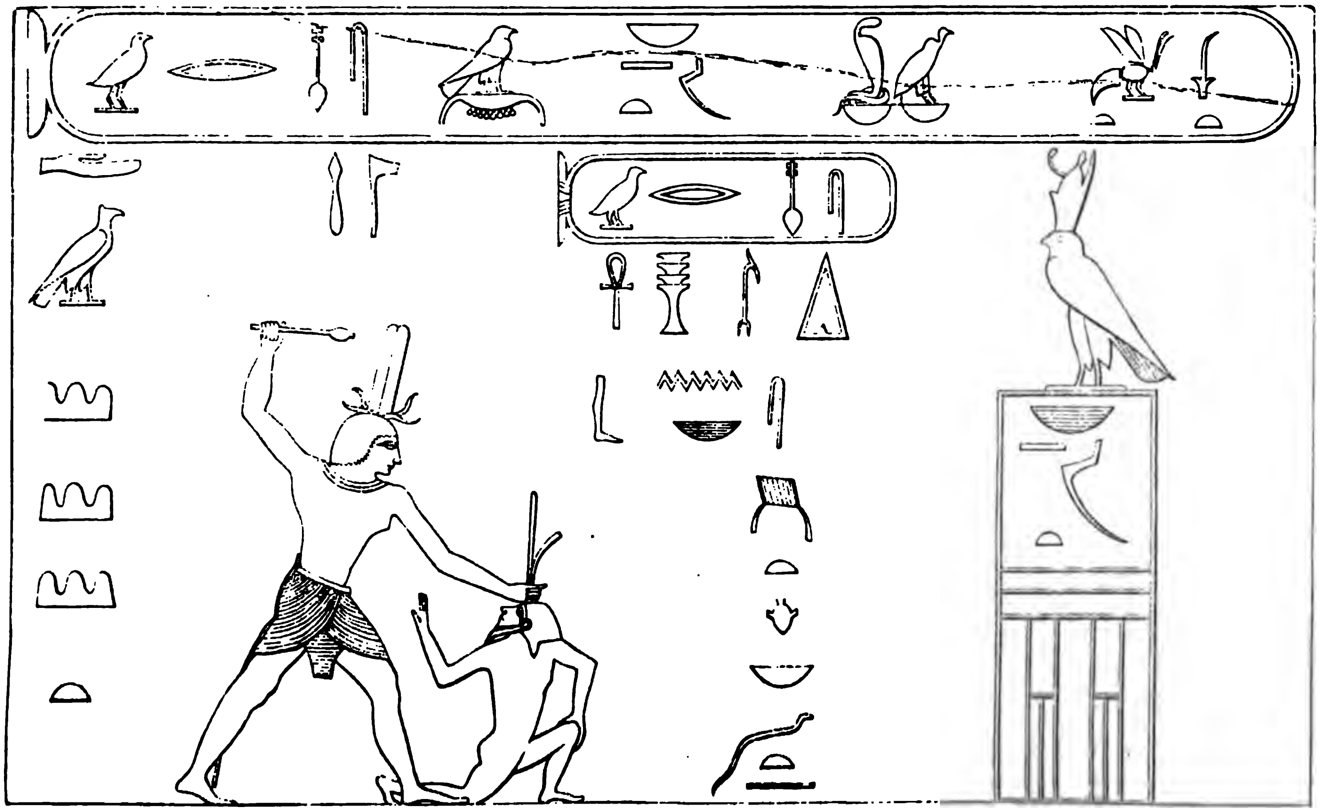


Fig. 2. Sephuris at Wady Meghara (Oldest Rock Tablets) Third Dynasty.

We have to remember, too, that the early colonists of Egypt came thither from Mesopotamia, a vast plain of sand, mud, and clay, where the buildings were erected of sun-dried bricks, and the necessity for Iron was on that account extremely limited as compared to that of another region wherein nature had provided the obdurate rock to be dealt with; also, that for the first two, and probably up to the seventh king of the third dynasty, the Mizraites confined themselves more or less closely to the banks of the Nile, at and about the Delta,* which is also of a Mesopotamian character, so that, as in their fatherland, these Mizraites during that period, and until they began to penetrate the country or were attacked by warlike neighbours, were not likely to feel the want of instruments or weapons of Iron, but in all probability continued to construct such temples or houses as were raised above the ground-level, of bricks dried in the sun and formed of the clayey mud of the Nile, as their forefathers had taught them in Shinar.

After the death of Sephuris the countries to the east of Egypt were still maintained under the yoke of the kings of Memphis. Accordingly, we find in the Wady Meghara a succession of rock-cut tablets, with the names of their successive Memphite kings, and the kings themselves depicted in the act of keeping the people in subjugation. Reference is now made to Fig. 3, respecting which we read—"Like his predecessor Sephuris, Soris had also to defend his north-eastern frontier against the desert rangers of Sinai." The subjoined tablet, Fig. 3, is inscribed on the barren crags of the Wady Meghara. It reads—" [HORUS], the hawk divine and great, the mace in all the lands of Monthra,† the subduer of all lands." The personage here discoursed of is the prince who holds his enemy by the hair, and smites him with the mace. This portion of the tablet refers to some military achievement accomplished in this neighbourhood by Soris when a prince. The rest of the tablet commemorates Soris as a king. It reads—"The lord of the festivals, King of Upper and Lower Egypt, Soris, ever-living." The two figures below represent Soris as King of Lower and Upper Egypt—

* It is, indeed, yet unproved that there were any actual buildings in Egypt constructed by native Egyptians until after the first Hyksos Invasion (commonly called the Shepherds), when that Shemitic community erected, or rather prevailed upon the monarch Shufu to erect, under their leader's superintendence, at the apex of the Delta the oldest building of all—the Great Pyramid. There was, however, plenty of excavation in the living rock, but nothing of architecture proper that we have yet ascertained.

† The God of War.

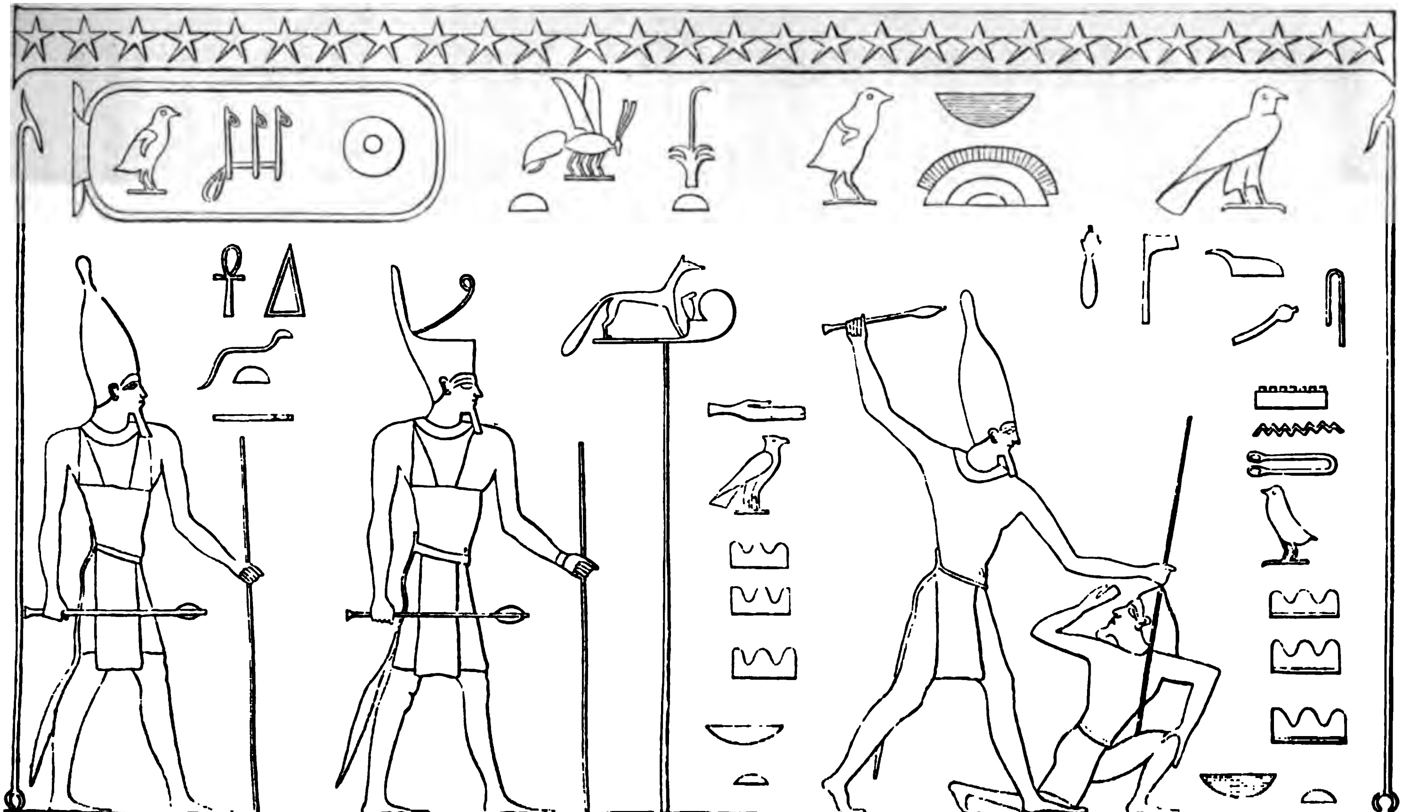


Fig. 3. Soris and the Canaanites at Wady Meghara (Oldest Rock Tablets). Fourth Dynasty.

i. e. of both banks of the Nile, in token of which dignities he wears the red and white portions of the *shent.* Immediately in front of him on a standard is the jackal, the symbol of vigilance. Above him are the starry heavens, supported by two sceptres, with the head of the Hoopoe, the symbol of purity.

That Soris reigned twenty-nine years, and that he was the first of a dynasty of Memphite kings, are the only particulars regarding him preserved in the lists.

Soris was succeeded by Suphis; and Fig. 4, also a rock tablet from Wady Meghara, represents him holding his enemy by the hair, and about to fell him with the weapon which he holds raised in the other hand.

Until the reign of Suphis there is no architectural monument to record—we mean in the sense of a built edifice; but in his reign and the co-regent reign of himself and his brother Nu-Shufu, we find ourselves suddenly confronted with the Great and Second Pyramids of Ghizeh; and whilst the existence of these, apart from any evidence of their actual growth from smaller and more imperfect preceding examples, has always been as great a puzzle to the inquirer as the solution of the question—By what means or tools the work of their construction was effected? I hope, at least, to have helped to clear the path of difficulty by having traced out almost to a certainty that Iron tools were supplied from the neighbourhood of Wady Meghara, which was held by the Memphite kings at the time the oldest monuments were erected; and the additional circumstance that they were held by force of conquest is not only testified by the Meghara tablets themselves, but also by the existence of the ruins of a vast fortress in the neighbourhood of the Ironworks.

Since the evidence in favour of an extremely remote use for Iron in Egypt has come to light, and bearing in mind that the Greeks were acquainted with the manufacture of Steel, as described by Aristotle, some persons have even ventured so far as to suppose that the find of Col. Howard Vyse's Engineers may probably be Steel also. I must confess that when at first, at the recent Congress of Orientalists, held last year in London, this was suggested to me by Dr. Lepsius, I paid but little heed to it; but when he especially directed my attention to the shape of the relic and its appearance, pointing out its being somewhat thick along the middle and tapering off as if to an edge on either side, after the manner of a scraper, for finishing and finally levelling the outer faces of dressed stone, I became impressed with the force of that great Egyptologist's suggestion.

A familiarity with the accepted methods of testing metals

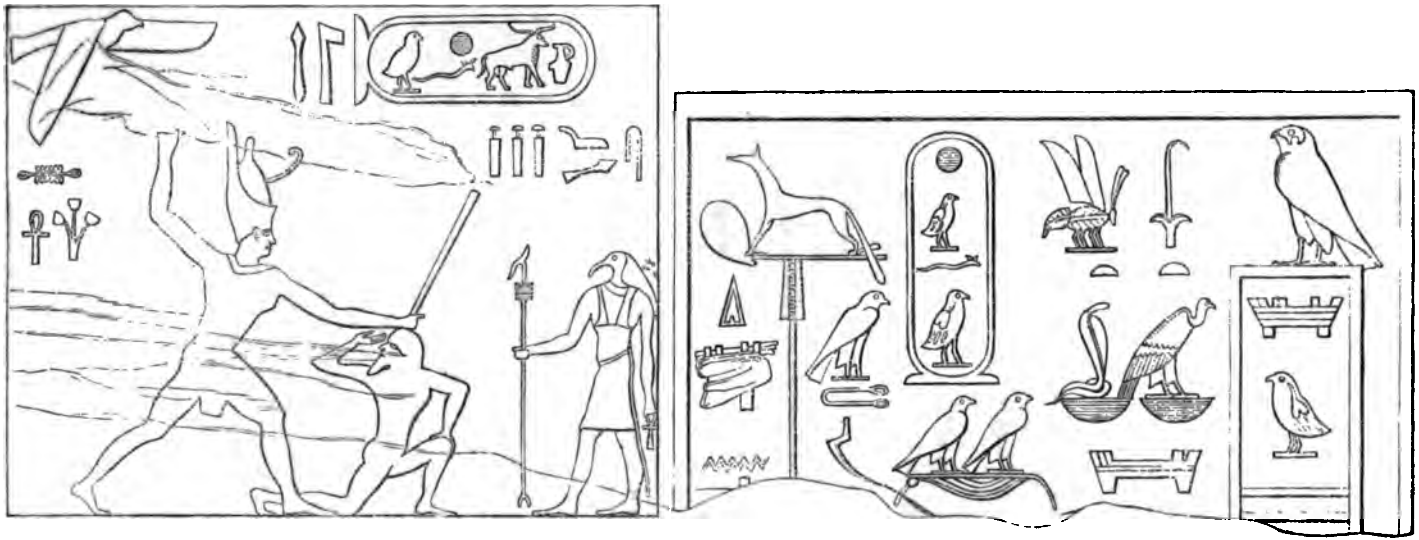


Fig. 4. Tablet of Suphis and Nu-Suphis at Wady Meghara. Fourth Dynasty.

naturally suggested to me that the question as to whether the relic was of Iron or Steel might, with a close approximation to certainty, be tested, by attempting to drill a hole in it, the relic, although much oxidised, being still for the most part in the metallic state. The conclusions to be drawn from such a test are, that if the drill easily and quickly penetrated the metal, then it must be Iron; that if, on the other hand, it resisted the action of the drill altogether, it was hard Steel; or if the drill penetrated but slowly then it was probably softer Steel. The writer having explained the proof which such a test would afford in ascertaining the character of the relic to Mr. Bonomi and Dr. Lepsius, they prevailed on Dr. Birch to consent to the writer drilling a hole in it, and in the presence of those interested the test was made on the 18th of September 1874, at the British Museum.

Having scraped off a little of the oxide near the thicker part of the fragment, the author commenced drilling, and finding that with a few rotations the drill easily penetrated the metal, he was at once convinced that it was soft Iron; the drilling was continued, but at the request of Dr. Birch the hole was not put through the Iron. The surfaces of the hole were examined, and had all the appearance of brightness and whiteness characteristic of newly-cut malleable Iron. To record the examination which has now been described, the following memorandum was drawn up by Dr. Birch, and signed by those who witnessed the test:—

"BRITISH MUSEUM, *18th September*, 1874.

"An examination by drilling of the fragment found near the channel of one of the air passages of the Great Pyramid, in the excavations undertaken by Colonel Howard Vyse.

"It was found that the fragment was of Iron, the drilling having penetrated it.

(Signed)
S. BIRCH.
ST. JOHN V. DAY.
R. LEPSIUS.
CHAS. SEAGAR.
J. BONOMI."

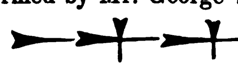
As the conclusive value, however, of a mechanical test may be called in question, it seemed desirable, that it should be confirmed or negatived by chemical evidence, and it was mentioned to Dr.

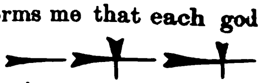
Birch, that a chemical analysis should also be made. On Dr. Birch's suggestion, I have represented to the Trustees of the British Museum the importance of knowing the chemical constitution of the relic, and that body has responded to my representation by instructing Dr. Flight to analyse it. As yet I have not received a report of the analysis, but when I do so I shall hope to communicate it to the Society.*

MESOPOTAMIA.

In the second paper on this subject read to this Society, I dwelt as far as was then possible on the use of Iron by the earliest inhabitants of that Interamnian plain, watered on one side by the Tigris, and on the other side by the Euphrates. Since then Mr. George Smith has carried out his excavations into the mounds there, and these have been productive in bringing to light several specimens of ancient Iron; none of them, however, are older than from 800 to 1000 B.C., yet I may be permitted to mention them, and in particular to refer to the Ombos of a shield as the most exquisite piece of ancient Ironwork I have met with—as a specimen of thin hammered Ironwork, I doubt if it can, in some respects, be surpassed by the productions of to-day.

Yet whilst Mesopotamia has not up to the present time produced any solid evidence in the form of material Iron relics belonging to the *oldest* monarchies, nevertheless the monuments of those earliest times are numerous, and they yield abundance of testimony to the acquaintance of the contemporary people with Iron.

I am informed by Mr. George Smith that the cuneiform symbol for Iron is  but that its phonetic value or pronunciation is not yet determined. It is found in inscriptions of all ages, and Mr. Smith says "must have been in use 2000 B.C." This, however, he informs me is not an Assyrian word, but one distinctly belonging to the ancient Babylonian or Proto-Chaldean people who inhabited the lower parts of the plain. There is, in fact, no pure Assyrian word for Iron, but this older one appears to have been grafted into the more recent Assyrian language.

In the inscriptions Mr. Smith further informs me that each god is mentior ith his sign, and this word  is the sig one of the gods of war and hunting, a symbol of his particular god-like attributes, a parallel indeed to the symbols we

* *Vide* Appendix, page 327, which has been received since the reading of this paper.

have found in the cartouche of the Iron King of Egypt, in the third dynasty of Memphis. Whilst on the one hand, then, Mr. Smith denies the discovery as yet of the phonetic value of this Proto-Chaldean symbol, on the other hand it should be mentioned that Professor George Rawlinson, of Oxford, has many years since published the word "*Hurud*"* as the Chaldean equivalent for Iron, but whether he gave this as the phonetic value for  I have until recently been in doubt. Uncertainty on that question is however now removed by the following statement in regard to the cuneiform signs, with which I have within the last week been favoured by the Rev. George Rawlinson, who, writing from Canterbury, says:—

"I delayed answering your letter until I could consult my brother on the subject, as I was not quite certain with regard to one or two points. I am now able to give you the benefit of his superior knowledge.

"There are two signs of metals in Assyrian with respect to which there is a doubt, which is Iron and which is Brass (or Bronze rather). These are  and . My brother on the whole inclines to regard  as Bronze and  as Iron. The former  is nowhere rendered phonetically, but the latter  is rendered in a syllabary as equivalent to *hurud* in Akkadian and *eru* in Assyrian. Mr. George Smith reverses the meanings of the two signs. The point is a very doubtful one."

CHINA.

Let us now then turn from those regions of the Old World, which are comparatively near, to those which are easternmost and vastly further removed from our ability to investigate. In a former paper † I drew attention to the extreme scantiness of our information respecting the state of the mechanical arts in China in very ancient times, but the labours of the Tsinologues in un-

* Vide *Five Great Monarchies of the Ancient Eastern World.* By Professor Rawlinson. London, 1871, vol. i., p. 62.

† Vide *Proceedings*, vol. viii., p. 24-7.

ravelling to the European mind the riches of that store of highly archaic literature which China possesses—a secular literature certainly as old, in all probability very much older than what is to be met with in any other country, asserted indeed to be at least 500 years older than the Hebrew Scriptures—have at last dispelled all doubt on the question, whether in China the use of Iron was known in pre-historic times. But this is not all, for in the most ancient Chinese writings mention is made of Steel, and Leih-Tze, an author who flourished about 400 B.C., describes the process by which it was made.

The oldest, and indeed the only Chinese word for Iron is

鐵 = *tie*: old sound *tit*.

It is mentioned in the list of articles of tribute—in the Yu Kung section of the Shoo King,* Book I., the tribute of Yu.

The following is the passage in which it occurs.

"The articles of tribute were musical gem stones, *Iron*, silver, *Steel*, stones for arrowheads, and sounding stones, with the skins of bears, great bears, foxes, and jackals, and articles woven with their hair."

In a note Mr. Legge adds, "by 鐵 = *tie*, we are to understand 'soft Iron,' and by 鏤 *low or lowe*, 'hard Iron' or 'Steel.' The latter article is often used for 'to cut' and 'engrave,' with reference to the hardness of the tools necessary for such a purpose. In the time of the Han dynasty, 'Iron masters' (鐵官) were appointed in several districts of the old Leang-chou, to superintend the Ironworks. Ts'ae refers to two individuals mentioned in the 'Historical Records,' one of the surname Ch'ǒ (卓氏)., and the other of the surname Ch'ing (程) both of this part of the Empire, who became so wealthy by their smelting that they were deemed equal to princes. 銀 is the white metal or silver."

* See Legge's *Chinese Classics*, vol. iii., pt. i., p. 121. Trubner, London 1865.

I am informed by the Rev. Dr. Edkins of Pekin, that with the exception of this passage there is probably no distinct allusion to Iron in writings older than 1000 B.C. The Book of the Shoo King is estimated as having been compiled about 2000 B.C., or at a time when in Egypt hieroglyphic tablet-writing flourished, and centuries before a Greek nation had begun to sensibly exist.

The place where the Chinese worked Iron in these most ancient times was at Shansi and Chilili, in the Ho district, where there are inexhaustible deposits of both Iron ore and coal, where too they have continued to work Iron to the present day; indeed at the present moment* a Commissioner of Li-hung-chang, the Governor-General of Chilili, and now the first minister of the newly appointed young King of China, is at present in this country commissioned to take out new appliances and apparatus for establishing in China Ironworks on the modern systems of operation. Tsze-chou is the town in or near which these works are to be established, and it is 200 miles south-west of Tien-tsin, where the Governor-General resides.

How many ages have rolled by since the Chinese were separated from those other families of the human race who spread westwards, and therefore away from them in their emigrations from the highlands of Asia, it may be impossible to determine; but now that we are able to decipher the Chinese literary records, the fact is proven, that about 400 B.C. their celebrated author and philosopher Leih-Tze, was acquainted with the native process for making Steel, and indeed with the property of tempering it. In the

康 = K'ang.

熙 = hi.

字 = tsi.

典 = tien,

* *Vide* Appendix, p. 322 *et seq.*, kindly supplied by the Commissioner, Mr. James Henderson.

or *Kanghi's Dictionary*, published about A.D. 1710, the author, quoting from the writings of Leih-Tze, reports him as saying in regard to Steel, that "a red blade" (by which I take it is meant a *reddish coloured* blade, red being one of the great variety of tints which a clean surface of Steel acquires in the process of being tempered) "will cut jade as it would cut mud." That it is the colour of tempering and not the redness of highly heated Steel to which Leih-Tze alludes, is evident from the manner in which he mentions it in that connexion as capable of cutting jade, a stone of great hardness, upon which it is almost unnecessary to add that red hot Steel could make no impression.

Reflecting, then, for a moment upon the long continued isolation and stand-still character of the Chinese race, by virtue of which they have not up to this time, like other nations, undergone phases of either retrogression or progression, but have remained unmoved with an almost if not a quite constant stock of knowledge, tradition, and superstition from the earliest times of their settlement, it is natural to conclude that if we should find in comparatively later times a record of a process for making Steel there practised, to thereupon infer that the Steel referred to in the book of the Shoo King and in the writings of Leih-Tze, was produced by the same or by a very similar process. Accordingly, in the "Pi-tan" or "Pencil Talk" it is said that Steel is made in the following manner: "Wrought Iron is bent or twisted up, unwrought Iron (*i.e.*, which may mean either Cast Iron or Iron ore) is thrown into it. It is covered up with mud and subjected to the action of fire, and afterwards to the hammer."

Making due allowance for the quaintness of the expressions used, and perhaps the difficulty which a mind untrained in the technicalities of Iron and Steel manufacture, must of necessity encounter in conveying to us fully the exact idea of what the account was meant by its writer to express, it is surprising how remarkably near to a well-known process for making Steel the above translation approaches, namely, that of immersing Wrought Iron either into molten Cast Iron, or heating it with Iron ore and fuel, covered over with layers of mud or clay, to exclude as much as possible the oxidising influence of the external atmosphere, thereby deoxidising the Iron ore by contact with excess of carbon, and producing a molten carburet, in which the Wrought Iron eventually becomes immersed as in a bath.

I have previously pointed out* that Aristotle describes the Greeks to have practised this identical process about 400 B.C. We have

* Vide *Proceedings*, vol. viii., p. 244.

then the fact of two celebrated authors and philosophers, one in China, the other in Greece, who flourished simultaneously but utterly unknown to each other, describing a similar method of making Steel practised at the same time in each country,—these countries separated by vast mountain ranges and impassable deserts, into the far East and West from the cradle centre of the human race, which fact, indeed, seems to me as one of great weight in the chain of evidence now being collected, to prove from authentic data the original unity of mankind. I have previously pointed out that the Greeks obtained their metallurgical knowledge, like almost every other knowledge they had, from the Egyptians; but it is not easy to mark out the channel by which this old Steel process was conveyed to the Allophyllian races of China from either the Semitic or Aryan nations located near the shores of the Mediterranean; indeed, the only way of accounting for the fact is by returning once again to the old doctrine of the original unity of the human race, and allowing to each section of mankind the carrying off with them that common stock of knowledge which the entire family possessed before separation, and of which there is abundant evidence on every side that working in the metals, and Iron in particular, formed a very important element.

The Chinese account of Steel-making at this remote epoch is, however, extraordinarily complete in that it describes and names the different kinds of Steel which are produced. The Steel produced by the first treatment, the Iron-workers call Ball-Steel—*twăn Kang* (from its rounded form), or Sprinkled Steel, *Kwan Kang* (from the pouring of water). There is what is called "False Steel," *weī teĕ*, and the account goes on to say, "When I was sent on official business to Tse Chow, and visited the foundries there, I understood this for the first time. Iron has Steel within it, as meal contains vermicelli. Let it be subjected to fire, 100 times or more, it becomes lighter each time. If the firing be continued until the weight does not diminish it is Pure Steel."

In the Pent Saow * it is said "there are three kinds of Steel,—

"*1st.* That which is produced by the adding of unwrought to Wrought Iron, while the mass is subject to the action of fire.

"*2nd.* Pure Iron many times subjected to fire produces Steel.

"*3rd.* Native Steel produced in the south-west at Hai-shan, and which is like in appearance to the stone called *Tsze-shih-ying*, purple stone efflorescence.

* A work of the Ming Dynasty, and Dr. Edkins informs me that the Pi-tan, already quoted, is probably also of that period.

"Steel is used for manufacturing swords and knives."

It is well known that Steel is still manufactured in China, and I have endeavoured to ascertain the process now used. This is, however, kept secret, and Mr. Henderson, to whom I have previously referred as Li-hung-Chang's Commissioner, at present in this country, explains to me "that the Steel which comes to Tien-tsin from the upper Yangstee is highly prized, and bears much higher prices than the Swedish Steel imported into China."

That the manufacture of Iron in early times must have reached considerable proportions is clear from another Chinese work coeval with the beginning of the Christian era, the name of which Dr. Edkins has promised to furnish me. It states that at that time a tax was levied upon Iron to contribute to the State Exchequer. Now it is clear that unless the manufacture had been a somewhat extensive one, it would not have been worth while to levy a tax upon it, for otherwise it could not have produced a revenue.

INDIA.

With regard to Indian iron manufacture I have, in the first place, to correct an error I formerly made * as to the date and place of the Iron Lâht at Delhi. From all that I could then gather it seemed to belong to a period ranging from the first to the fourth century of the present era; but since that time Lieutenant Cole's magnificent work † on ancient Delhi, of the existence of which I was not then aware, indeed it does not appear to have been published at the time my paper, which especially referred to the Lâht, was written —has come under my notice.

The Iron column instead of being situated where I formerly stated, is, I now find, in the axis of the colonnade of the Masjid-i-Kutb-ul-Islam.

M. Garcin de Tassy ‡ has translated the Persian account of the column written by Syud Ahmed, and has supplemented it with some weighty remarks, from which it appears to have been set up by an otherwise unknown king, Rajah Dhava, *alias Midhava*, and whilst it now seems that the forging was made in the 9th century B.C., or from 1100 to 1200 years earlier than I had formerly stated, yet the inscrip-

* Vide *Proceedings*, Vol. viii., p. 251, *et seq.*

† *The Architecture of Ancient Delhi, especially the Buildings around the Kutb Minar.* By Henry Hardy Cole, Lieutenant R.E., late Superintendent of the Archæological Survey of the North-Western Provinces of India. London: Published by the Arundel Society, 1872.

‡ *Les Monuments d'Architecture de Delhi.*—*Journal Asiatiques*, July, 1860.

tion upon it is of much later date, M. de Tassy concluding the inscription to be possibly as late as the third or fourth century of the present era, and inscribed therefore by a king long subsequent to its originator, who, indeed, we learn from Indian history, died in the course of its construction. I have also to add that a cast of this remarkable column is now on view at the South Kensington Museum; also, that a piece of the metal has been cut from the pillar, and this piece has been both forged and analysed by Dr. Percy, who has pronounced it as soft *Wrought Iron.*

Whilst speaking of India, I cannot, however, pass over that unique collection of archaic Iron and Steel tools which Colonel Pearse, R.A., found in excavating some tumuli at Wurree Gaon, near Kamptee, in India, which tumuli are believed to date from about 1500 B.C., or the time of Moses; and whilst we have no such solid relics of the tools used by the Hebrew race, yet we know from words in the Hebrew language that they were well acquainted with Iron in all its forms (see the appended Table), and this discovery (which, if the date assigned by Colonel Pearse be correct) shews at least that the contemporary nations were well acquainted with Iron and Steel; that their language, too, the Sanskrit, in its oldest forms has corresponding words for Iron, Iron ores, &c.

Colonel Pearse has presented his "find" to the Trustees of the British Museum, and I lately was fortunate in receiving from Colonel Pearse himself a full explanation of the several implements, which include gouges, spatulæ, ladles, and a variety of other articles.

The appended Table shews, from the evidence of language, that Iron was known amongst the most ancient nations in the very earliest times up to which it is possible to trace their existence.

CONCLUSION.

Having thus, I fear, seemed to have traversed over too wide an area for a single paper to discuss, yet hoping not to have wearied you with the details into which I have found it necessary to the due exposition of facts to enter, it will, I think, be conceded that in my very humble efforts to peel off some of the scales, the rust with which unyielding testimony from the oldest times has been corroded, I have at least laid bare a concatenation of facts out of which there is no escape from the conclusion that in all the earliest peopled countries, whether peopled by Semitic, Hamitic, Aryan, or Allophyllian races, there is most certain proof that in the remotest ages which we can ascertain anything about, the inhabitants were

familiar with the use and practical manufacture of Iron and Steel; that in those countries there is not a tissue of evidence in favour of a Bone or Stone age, still less of a Bronze and then an Iron age succeeding; that from the evidence adduced, and which indeed is being continually supplemented, it is evident the Stone, Bronze, and Iron theory must be consigned to the limbo of false ideas and exploded notions!

I cannot, however, close without expressing my indebtedness for invaluable aid in the preparation of this communication to Professor George Rawlinson of Oxford, and his brother, Sir Henry Rawlinson; to Dr. Birch, and Mr. George Smith, of the British Museum; to the Rev. Dr. Edkins, of Pekin; and last, though not least, to that prince of Egyptologists, Dr. Lepsius, of Berlin, who indeed has placed his valuable researches in my hands, and to which I may hope to draw attention on some future occasion.

APPENDIX.

CHINESE IRON MANUFACTURE.

THE day following the reading of the foregoing paper, Mr. Day was furnished by Mr. Henderson, the Commissioner from Li-hung-Chang to this country, with the subjoined "Notes from his Diary" during a ramble through Shansi in March 1874, which, containing useful information on the subject of the foregoing paper, the Physical Section have recommended to be published as an Appendix to Mr. Day's paper.

STEEL.

Mr. Henderson says: "In formerly writing you, I mentioned that Steel is made at or about Hankow, on the Yangstee, which still is considered very valuable by the Chinese, and brings a much higher price amongst them than the best English or Swedish Steel imported. How this Hankow Steel is made, I cannot say. I saw no Steel made, but some of the Iron is very fine; and when reheated by wood may, no doubt, have some of the properties of Steel."

IRON.

Regarding the native methods of making iron, Mr. Henderson has succeeded in obtaining much more complete information, as

contained in the following, which, to make intelligible to Europeans, he has prefaced with a table of arithmetical values.

CHINESE COINS AND WEIGHTS VALUE.

One tael of silver is valued at .		6s. 0d.
Number of cash in a tael, is	1680, .	6s. 0d.
cash	280, .	1s. 0d.
cash	140, .	0s. 6d.
cash	$23\frac{1}{2}$, .	0s. 1d.

In the calculation of silver money,

10 cash makes one condarin.
10 condarins one muci.
10 muci one tael.

In the weight of coals or other bulky goods—

100 catties is equal to 1 pecul,
1 pecul „ $133\frac{1}{3}$ lbs. avoirdupois.
16 peculs ·80 catties is equal to 2240 lbs. or 1 ton.

IRONWORKS 10 TO 13 MILES FROM YANG-CHING SHANSI, CHINA.

On the northern side of the valley stand the smelting establishments. There seemed to be eight or ten of them, with immense heaps of broken moulds before them.

Behind the Ironworks are the low hills, containing both the coal and the Iron ore. Visited one of the smelting establishments; they have been well described by Baron Richtopen and Dr. Williamson. Saw the anthracite coal and the Iron ore. Coals cost at the hills behind the works 20 to 25 cash (1d.) per basket of 80 catties (107 lbs.), and never exceed 30 cash. Iron ore, inferior, cost 20 cash (1d.) per pecul, and for the very best about 50 cash (2d.) per pecul (133 lbs.) at the mountain. By a pecul our informant meant as much as a man could carry. In smelting, 100 peculs of Iron ore, if very pure, yields 90 catties of Iron; if slightly inferior, 85 catties, and if common, 80 catties. On a second smelting the Iron loses 10 per cent., some say 5 per cent., and is then made into pots and pans of Cast Iron, but as the goods contain some of the sand, the loss in Iron is only about 5 per cent. The third time the Iron is smelted it is made into bars. By this time the original 90 catties has come to be only 70 catties, or even less, if not very good. To be made into other articles it may be smelted four, five, or six times, and in the latter case it is fit for needles.

We saw the open furnaces, in which were 66 crucibles, and which take a day and a half to smelt. The smeltings turn out very unequally; the 66 crucibles may turn out 8 peculs in all, if very good ore, and if poor ore only 5 peculs. The produce of the first smelting sells at 5 cash per catty, and the Bar Iron of the third smelting at 16 cash, at this place.

Following the bank of the Ching-ho we came by the river side to some smelting establishments. At this place they did not smelt from the ore, but purchased the Iron after it was smelted at 5 cash per catty, and from this they made their pots and pans. Here they told us that on smelting a second time for castings, the out-turn was only about 70 per cent. of the first smeltings.

At Zuang-yin-san the owner of the mountain carries his Iron to a distance of 30 li (10 miles), and sells it to the manufacturers at 200 cash for 300 catties, allowing 3⅓ cash per pecul per li for carriage. This would give the value of the ore of the mines as being 33⅓ cash per pecul (1⅓d. for 133 lbs.). Kung-san Iron is not so good, 4 taels weight (or 25 per cent.) cannot be got out of a catty.

At these places the Iron is very soft, and in appearance like coarse-grained red sandstone.

At Su-chuan there is a large smelting establishment, the smelting being done in large pits, each holding about 25 peculs of ore. The smelting occupies one day, and after smelting it is allowed to remain in the pit one day to cool; it comes out in one piece, weighing apparently about 6 peculs, and is sold in this state at 5 cash per catty.

They could not tell us how much coal was used to smelt one of these masses of Iron.

The workmen are paid 60 cash per day and food, food consisting generally of small millet and a little salt, no vegetables, and may cost about 20 cash.

This Iron is of the same description as we saw at the Chung-ho establishment, which loses 30 per cent. on being smelted a second time.

Visited another large establishment, where they made principally *Bar Iron;* at the first smelting the ores give 25 to 30 per cent. of Iron. This was smelted a second and a third time for bars, when it again lost 20 per cent., the proceeds of the first Iron giving only 80 per cent. This Bar Iron is said to sell at 20 cash per catty. We

saw at this establishment many of the little cops of Iron which came out of the crucibles, and they differed greatly in thickness and in weight, being from 5 to 8 catties.

Here we also saw an immense oblong stack of firewood, some 60 × 20 × 20 feet, for use in smelting where Bar Iron is to be made.

At Ping-ding-chow, or 7 miles north of it, we entered the first smelting establishment we came to.

They had here in the open furnace 128 crucibles, these crucibles being about 4 feet high, and 6 to 7 inches in diameter. Out of these 128 crucibles they would get about 15 peculs of Iron, equal to about 40 per cent., to smelt which will take about 10 mule loads of coal—*i.e.*, about 20 peculs or 1¼ tons; the produce of the first smelting sells at 5 cash per catty.

At the second establishment we were told that out of the coarse yellow Iron ore they could get 40 per cent., and out of the best dark ore they could get 60 per cent. They were mixing here the two kinds of ore. It was all pounded small before being put into crucibles. In the second smelting, if Wrought Iron is to be made of it, wood alone is used, thus making it fine and tough; for the third or fourth smelting coal is again used.

At a third smelting establishment they were making moulds for pans. The first smelting here will produce about 60 per cent. from the ore, but this contains a great deal of impurity; and upon this being smelted a second time, it will again turn out only about 60 per cent. of the first smelting. The contents of 128 crucibles of the first smelting are put into 63 crucibles, and these turn out on a second smelting enough Iron to make about 50 pans.

Time required for the first smelting, 2 days; for the second smelting, 1 day.

The Chinese idea of percentage of Iron from the ore is evidently a purely imaginary one, for they never weigh the ore. With coal and Iron ore both so plentiful and cheap, the Iron is so much per donkey load, as much as the animal can carry.

Some Iron ore we purchased at Ping-ding Chow, shewed, at the Royal School of Mines, London, to contain 50 per cent. of Iron. It is loose hematite, and contains little or no sulphur.

INDIA.

Mr. Henderson at the same time has forwarded the following letter from Mr. Bourne, and has Mr. Bourne's sanction to publish the same :—

66 Mark Lane,
London, E.C., *26th April*, 1875.

James Henderson, Esq.

My Dear Sir,

I have seen the native process of making Iron in many parts of India, and it is substantially the same in all. A furnace—of say 20 inches internal diameter—is built of clay, breast high, and has the pipes of some sort of bellows entering at the bottom: while the charcoal and the ore, broken into small pieces, are put in at the top. After blowing for some time a hole is opened, about half way up, in the front of the furnace, out of which a large mass of Spongy Iron is taken, and this mass is re-heated and hammered into small ingots sharpened at each end, in which state it is sold. The late Mr. Heath informed me that he has seen furnaces in India about three times the height of the foregoing, which furnaces produced Cast Iron, the sole use of which was to melt with Wrought Iron for the production of Steel, as is now done in the Bessemer process. But these furnaces I never myself came across, and they are not common. The wootz is produced by melting Wrought Iron in small crucibles, into which some twigs and a green leaf from a certain tree are introduced, and the crucibles are then stopped with clay formed into a pyramid, over which a dome is built, and heat is applied, when the Wrought Iron melts and combining with the charcoal of the green twigs forms Steel. Charcoal will not do as a substitute for the green twigs. The Steel takes the shape of half the crucible, and is of the shape and size of half an egg. In making the Damascus blades each piece of wootz was drawn out into a riband of the proper length, and a bundle of these ribands was then welded together. This process produces the exact markings to be found on the old Damascus blades.

Regarding the testimony touching the antiquity of Iron, I may mention that shortly after my first visit to India I came across a book of Egyptian hieroglyphics and drawings, where one of the objects represented was the manufacture of Iron after precisely the same fashion as I had seen it practised in India. If I had not been in India I should not have known what was intended to be represented; but having seen the mode of procedure in India I recognised it at once. I do not now remember what the book was in which I saw

this, or what epoch it was supposed to represent. But this, no doubt, could be discovered by any one who knew the Indian mode of manufacture, and who was interested in the subject.

I remain,

Yours very truly,

JOHN BOURNE.

ANALYSIS OF IRON FROM THE GREAT PYRAMID.

The following letter to Dr. Birch, Keeper of the Oriental Antiquities at the British Museum, describing the chemical constitution of the piece of Iron found by Colonel Howard Vyse in the Great Pyramid, having been received since the foregoing paper was read, is here inscribed as descriptive of the character of the oldest piece of Iron known.

MINERAL DEPARTMENT, BRITISH MUSEUM,
12th May, 1875.

DEAR DR. BIRCH,

The result of my examination of the fragment of Iron (?No. 3453) from the air-passage of the Great Pyramid, goes to shew that *it is not of meteoric origin.* It contains, it is true, a trace of Nickel, but it is only a trace. It is, in fact, by no means an uncommon occurrence for a trace of that metal to be met with in manufactured Iron, derived from its various ores; and several analysts have detected the presence of Nickel oxide in the ores likewise. According to Pattison (*Brit. Assoc. Rep.*, 1864, p. 49) the Cleveland Ironstone contains in 1 lb. of ore 0·72 grain of Nickel and 0·12 grain of Cobalt. O. L. Erdmann (*Jour. Prakt. Chem.*, xcvii. 120) states that he has many times found traces of Cobalt (the *alter ipse* of Nickel and constant associate of Nickel in meteoric Iron) in Iron ores, and still more frequently in samples of commercial Iron. It should be stated, by the way, that the presence of a trace of Cobalt is more readily recognised than the same amount of Nickel would be. C. O. Brann (*Zeit. Annl. Chem.*, v. 226) mentions the fact that in many analyses of Iron which have been carried out in the Wiesbaden laboratory, the presence of Nickel

and Cobalt has been recognised. G. Lippert (*Zeit. Annl. Chem.*, ii. 41) found in the Spiegeleisen, obtained from the Spathic Iron ore of Stahlberg, near Musen, 0·016 per cent. of Nickel and a trace of Cobalt.

The fragment of Egyptian Iron contains combined carbon, an occurrence of great rarity in meteoric Iron. The locksmith who removed it from the specimen tells me that under the saw it behaves like Wrought Iron, and I find its magnetic character to accord with Wrought Iron rather than with Steel.

Believe me, Dear Dr. Birch,

Yours very truly,

(Signed) WALTER FLIGHT.

ERRATA IN THE ACCOMPANYING TABLE.

In the Hebrew Phonetic Values for *Nŏoshvoth*, read "*yāh-shooth;* and for *Mvutsok*, read *moo-tzāhk'*

XXVIII.—*The Ageing of Whisky and other Spirits.* By Dr. WILLIAM WALLACE, F.R.S.E., F.C.S.

[Read before the Society, April 28, 1875.]

DR. WALLACE described the process patented by Mr. E. W. Phibbs for treating alcoholic liquids, whereby the effects of age are conferred by subjecting the spirits to the action of heat. In practice the spirits are usually maintained at a temperature of about 270° Fah. for two or three hours. By the kindness of Mr. Napier Smith, Dr. Wallace was enabled to exhibit a working model of the apparatus, capable of containing about three gallons of spirits, and also samples of whisky before and after treatment.

MR. JAMES R. NAPIER said that Pasteur has stated that new wine contained in close vessels, free from the contact of the air, does not deposit, does not change colour, does not take bouquet; and that the same wine submitted to the influence of the oxygen of the air deposits considerably, even to becoming muddy; that it loses entirely the character of new wine, and that its colour becomes that of a wine 10 or 20 years old; that it also, as is well known, becomes sour in time, but that by heating it to between 140° and 150° Fah., or even less, the quality of the wine is not injured but improved, and it acquires an extraordinary resistance to all kinds of maladies, and becomes old wine in a few weeks; that the parasites in the wine itself are destroyed at these temperatures.

XXIX.—*The Germ Theory of Putrefaction.* By DR. WILLIAM WALLACE, F.R.S.E., F.C.S.

[Read before the Society, April 28, 1875.]

DR. WALLACE mentioned a striking illustration of the germ theory of putrefaction in Fryer's patented process for the preservation of

meat. Hitherto the sole aim in preserving meats in tins was to get rid of every trace of oxygen, and Dr. Wallace described the various methods by which this was accomplished. Fryer's process consists in simply inclosing the meat in tins, soldering them up without any attempt to expel or absorb the oxygen of the air, and exposing them for sufficient length of time to the action of heat to cook the meat. The germs constantly floating about in the air are at the same time destroyed, and the meat keeps fresh for any length of time. Dr. Wallace exhibited, by the kindness of Mr. Napier Smith, two tins of meat prepared three years ago in New Zealand; one of these was opened and found to be perfectly fresh.

XXX.—*Fractured Rivets from a Steam-Boiler.*

By James R. Napier, F.R.S.

[Read before the Society, April 28, 1875.]

Some leaks having lately been observed at the heads of the rivets of a cylindrical boiler working at an absolute pressure of about 70 lbs. per square inch, an attempt was made to stop them by rehammering the rivets. It was then found that the heads dropped off, and in the act of hammering up the new rivets the heads of others dropped off, and so it happened to about a dozen rivets.

[In the specimens of fractured rivets exhibited some were fractured all round, but still attached at the head made by the riveting machine, and others fractured all round at bat or cressed head put on by the riveters; others were fractured nearly through close to the machine-made head, and only held from dropping off by a small lune, while others shewed the same fracture at the riveters' head.]

I have no opinion to offer as to the quality of the iron, except that it is very unsuitable for hot riveting, and would be very unhappy were I owner of such a boiler, until every rivet in it was examined, or the boiler proved to be capable of resisting at least twice its working pressure.

XXXI.—*On a Method of Spinning Tops.*

By JAMES R. NAPIER, F.R.S.

[Read before the Society, April 28, 1875.]

UPWARDS of twenty years ago, I bought for one of my children the biggest humming top I could find. It was about 6 inches diameter, but the child could not spin it. I removed the handle, cut a notch on the end of the axis, and put the middle of the cord in the notch; then laid the two parts parallelly round the stem, like a double-threaded screw-bolt, and when a sufficient quantity of cord was wound, secured one of the parts in each hand, and pulled both vigorously, holding the top as vertically as possible. It dropped on the floor, spinning beautifully, and the child could spin it.

[A number of tops of various sizes were shewn spinning on the table.]

XXXII.—*On the Conical Filter of Greatest Capacity for a given Sla[nt] Height or Radius of Filter Paper.* By JAMES R. NAPIER, F.R.S.

[Read before the Society, April 28, 1875.]

HAVING recently had occasion to filter a quantity of oil and al[so] wine through paper, it occurred to me that the ordinary method [of] forming the filter by folding the paper into four sectors of nine[ty] degrees each was erroneous; that a filter, to contain a great[er] quantity with more filtering surface, could be made with the sa[me] paper.

The problem is easily solved by the well-known rules of t[he] differential calculus. The result gives a cone whose

$$\text{Radius of base} = \text{slant height} \times \sqrt{\tfrac{2}{3}}\ ;$$

or radius of base of cone = about $\frac{4}{5}$ radius of paper.

In the ordinary filter only half the paper is available; in th[e] form four-fifths of it is available.

XXXIII.—*Note of Experiments with Giroud's Rheometer.* By Mr. WILLIAM FOULIS.

[Read before the Society, April 28, 1875.]

GIROUD'S Rheometer is an apparatus for maintaining a unifor[m] rate of combustion of gas at all pressures. It consists of a lig[ht] metallic bell, floating base downwards in a chamber partly fille[d] with glycerine. The gas from the main enters the bell and escap[es] by a small hole in its roof. The rise or fall of the bell, as the pre[s]sure of gas rises or falls, reduces or enlarges the opening from th[e] glycerine chamber to the jet, by means of a small cone on centre [of] roof of bell; thus, the difference of pressure between the main an[d] the jet is expected to remain constant—equal, in fact, to the weig[ht] of the bell per unit of area of its base.

The following experiments made by me shew how nearly this has been realised :—

PRESSURE OF GAS IN MAIN. (INCHES OF WATER.)	½ In.	1 In.	1½ In.	2 Ins.	2½ Ins.	3 Ins.
Bat-Wing Burner,	2·5	2·6	2·5	2·5	2·5	2·5
,, ,, . No. 3	1·6	2·6	2·6	2·6	2·6	2·6
,, ,, . No. 1	1·5	2·5	2·6	2·6	2·6	2·6
Union Burner, .	1·7	2·6	2·6	2·6	2·6	2·5
,, ,, . No. 4	2·0	2·6	2·6	2·6	2·6	2·5
,, ,, . No. 3	2·0	2·6	2·6	2·6	2·5	2·5
,, ,, . No. 2	1·6	2·5	2·6	2·6	2·6	2·5
,, ,, . No. 1	1·0	1·5	2·0	2·4	2·6	2·6
,, ,, . No. 0	1·0	1·6	2·1	2·5	2·6	2·5
No Burner, . .	2·5	2·6	2·6	2·6	2·5	2·5

N.B.—The larger figures in the columns indicate the *rate of combustion in cubic feet per hour.*

MINUTES OF SESSION.

November 4, 1874.

The Philosophical Society of Glasgow met this evening in the West Hall of the Corporation Galleries, Professor Grant, LL.D., the President, in the Chair.

Letters were read by the Secretary from the five new Honorary Members, acknowledging their election, viz.:—

Lewis Dunbar Brodie Gordon, Esq., C.E., F.R.S.E., F.C.S., London; Robert Lewis John Ellery, Esq., F.R.A.S., Victoria; Professor Andrew C. Ramsay, LL.D., F.R.S., London; Dr. Joseph Dalton Hooker, F.R.S., London; Dr. R. Angus Smith, F.R.S., F.C.S., Manchester.

Mr. James Hislop, Gas Manager, Maryhill Gas Works, was elected a member of the Society, having been proposed at the closing meeting of last Session.

Mr. George Watson and Mr. Peter W. Dixon were appointed auditors of the Treasurer's Accounts.

The President delivered an Opening Address, taking for his subject the recent progress of Astronomical Science.

On the motion of Mr. David Mackinlay, the thanks of the Society were voted to Dr. Grant for his address.

Mr. James Thomson, F.G.S., read a paper in continuation of the results of his investigations into the Corals of the Mountain Limestone of Scotland; with a description of a new genus of Corals from Thirdpart, near Beith, Ayrshire.

Mr. Wünsch and Mr. John Young, of the Hunterian Museum, bore testimony to the great importance of Mr. Thomson's investigations.

On the motion of Mr. John Mayer, it was remitted to the Council to prepare a minute on the death of Dr. Thomas Anderson, the late Professor of Chemistry in the University of Glasgow, and for several years an Office-bearer of this Society; and to transmit to Mrs. Anderson an expression of sympathy in her bereavement.

Mr. Mayer suggested that a Committee should be appointed to take some definite action in connection with the Mitchell Bequest

to this city. He thought it very desirable to ascertain whether a Museum could be established along with the Library.

The subject was discussed by Dr. Fergus, Mr. James Thomson, Mr. J. C. Burns, and Mr. N. Dunlop, and it was remitted to the Council to take whatever steps might be deemed necessary in the matter.

November 18, 1874.

The Seventy-third Annual Meeting of the Philosophical Society of Glasgow, for the Election of Office-bearers and other business, was held this evening in the West Hall of the Upper Corporation Galleries, Professor Grant, LL.D., the President, in the Chair.

The Minutes of last meeting having been read and approved of, the following notice, by the Council, of the death of Dr. Thomas Anderson was read and approved of:—

"The Council of the Philosophical Society have heard with sorrow of the death, at Chiswick, on November 2, of their former Associate, Dr. Thomas Anderson, late Professor of Chemistry in the University of Glasgow. Dr. Anderson became a Member of this Society in 1852; he was elected a Member of Council in 1854; was appointed to the office of Librarian in 1856; for a few years he edited the printed *Proceedings* of the Society; in 1859 he was elected President; from 1862 to 1868 was a Member of Council, and was subsequently President of the Chemical Section. He conducted for many years a series of original chemical researches—the results of which were recorded in numerous Papers published in the *Philosophical Transactions*, whilst in the *Transactions of the Highland and Agricultural Society of Scotland*, of which Institution he was the Chemist, he gave to the world another important series of Papers on the Application of Chemistry to Agriculture. The scientific investigations in which he was so long and honourably engaged, apart from the laborious avocations of his Professorial Chair, were unhappily arrested some years ago by the failure of his health; and now death has closed his useful career at the comparatively early age of fifty-five. With many tender recollections of his amiability of character and disposition, and of the pleasant intercourse they maintained with him during his connection with this Society, to which he rendered much willing service, his former associates lament his loss as that of an old and tried friend; and resolve to communi-

cate to Mrs. Anderson and her family an expression of sincere sympathy in the mournful bereavement they have sustained."

The following were elected members of the Society, viz.:—

Mr. John Clapperton, Manufacturer, 5 Sandyford Place; Mr. William G. Taylor, Jun., Jeweller, Gartmore Villa, Battlefield, Langside; Mr. Thomas Muir, M.A., F.R.S.E., High School, Glasgow; Mr. James Parnie, 26 Lynedoch Street; Mr. John Brown, Manager to Messrs. Thomson & Co., Patent Agents, 62 Buchanan Street; Mr. John Spencer, Merchant, 2 Rosslyn Terrace, Dowanhill; Mr. Thomas Short, 4 Kelvingrove Street; Mr. Colin B. Fairlie, C.E., 67 Renfield Street.

The Secretary read the Council's Report on the State of the Society, which was approved of.

Report of the Council on the State of the Society.

1. *State of the Membership.*—At the beginning of Session 1873–74, the number of members on the roll was 570. In the course of the Session 49 new members were admitted, making in all 619—of whom 11 resigned, 8 left Glasgow, their names being placed on the suspense list, and 9 died—reducing the total by 28, and leaving on the roll 591. Of the whole number, only one member is in arrears of annual subscription for two years, and four members are in arrears for one year.

At the meeting in April 15, the Society added to its list of Honorary Members the names of Lewis Dunbar Brodie Gordon, Esq., London; Robert Lewis John Ellery, Esq., Victoria; Professor Andrew Crombie Ramsay, London; Dr. Joseph Dalton Hooker, London; and Dr. R. Angus Smith, Manchester.

2. *New Section.*—A Section of Physics, including Mechanics and Engineering, was formed at the close of last Session.

3. *The Proceedings.*—The printed *Proceedings* of last Session form the first number of the ninth volume, and, including the Minutes of the Society's meetings, list of Books added to the Library, and list of members of the Society, extend to 152 pages. The following Papers are contained in the number, viz.:—"On some Indications of a Daily Periodicity in the Vital Functions of Man," by Dr. James Finlayson. A lecture delivered before the Society (by an arrangement with the Chemical Section), "On Water Supply," by Dr. Stevenson Macadam, Edinburgh. "On the Economical Combustion of Coal Gas," by Dr. Wallace. "On the Economy of Fuel in Domestic Arrangements," by Mr. James R. Napier; who also

contributed a paper "On the Cubic Space and on the Volume of Air necessary for ensuring the Salubrity of Inhabited Places," and a third, "On the Effect of Loch Katrine Water on Galvanised Iron." Dr. Thorpe delivered an experimental lecture "On the Measurement of the Chemical Action of Sunlight," an abstract of which is printed in the *Proceedings.* Professor Sir William Thomson, LL.D., made a communication "On Deep-Sea Sounding by Piano-Forte Wire."

From the Chemical Section the Society received a paper by Professor Gustav Bischof "On the Analysis and Purification of Water," and another by Mr. J. J. Coleman, "On the Methods in Use for determining the Value of Animal and Vegetable Oils."

The discussions which followed the reading of most of the papers are reported in the *Proceedings.*

Amongst the unprinted proceedings of last Session are the address of Professor Grant, the President, at the opening of the Session; a communication on the same evening by Mr. James Thomson, F.G.S., "On the results of his investigations into the Corals of the Mountain Limestone;" a discussion, which lasted two nights, on "The Sewage Question," introduced, at the request of the Committee on Papers, by Dr. Fergus; a lecture by Professor James Thomson, LL.D., "On the Gaseous, the Liquid, and the Solid States of Matter;" a communication by Professor Sir William Thomson, LL.D., "On Improvements in the Mariner's Compass;" a description by Professor Grant of Croudace's "Stellar Azimuth Dumb Compass;" a description of his "Patent Electric Fire Alarm," and his "Patent Sewage Filter," by Mr. Symington; and a communication "On some recent Classifications of the Elements," by Mr. John Ferguson, University Chemical Laboratory, and since appointed Professor of Chemistry in the University of Glasgow.

Mr. Day read the Library Committee's Report on the Library, which was approved of.

Library Committee's Report.

With respect to the state of the Library, the Library Committee have to report the purchase, during the Session 1873–74, of thirty-two volumes and six pamphlets, making the additions to the Library, in respect of purchase, thirty-eight since the date of last Report.

In the same period the Library has received two hundred and twelve donations, consisting of sixty-eight volumes, forty pamphlets,

and one hundred and four parts. In this list of donations is included one consisting of a large number of books and pamphlets which belonged to the late Professor Rankine, presented to the Society through Mr. J. R. Napier from the Professor's executrix.

Thirty-nine British and foreign periodicals are received at the Library.

Altogether, the Library has had two hundred and eighty additions during the Session.

The binding of books and periodicals is regularly kept up, one hundred and twenty-nine volumes being bound and in course of binding during the year.

The Society exchanges publications with seventy-six different Societies and individuals, shewing an increase of two since last Report.

With reference to the purchase of new books, it is hoped that during the coming Session these will be more numerous, especially in view of the prospect of several works on important subjects in which this Society is interested being already announced as in the press; but to enable the Library Committee to meet the wishes of the members as far as possible, the Committee urge upon the members to aid them with suggestions and recommendations.

Appended to this Report is a list of books bought, donations, and periodicals received during the Session.

The Treasurer's Statement of Accounts for Session 1873–74 having been printed in the Circular calling the meeting, was held as read, and approved of. The following is an abstract:—

ABSTRACT OF TREASURER'S ACCOUNT.

SESSION 1873–74.

DR.

1873. Nov. 1.		
To Balances from last Session—		
In Union Bank of Scotland, ...	£99 16 10	
In Treasurer's hands, ...	8 19 3	
		£108 16 1
1874. Oct. 31.		
To Entry Money and Dues from 49 New Members, at 42s., ...	£102 18 0	
,, Annual Dues from 4 Original Members, at 5s.,	1 0 0	
,, Annual Dues from 550 Members, at 21s., .	577 10 0	
		681 8 0
Carry forward, . . .		£790 4 1

Brought forward, . . .				£790	4	1
To Chemical Section.—1 Associate, for 1870-71, at	£0	5	0			
1 ,, for 1871-72, at	0	5	0			
4 ,, for 1872-73, at 5s.,	1	0	0			
33 ,, for 1873-74, at 5s.,	8	5	0			
				9	15	0
,, Sanitary Section.—37 Associates for 1873-74, at 5s., . . .				9	5	0
,, Corporation of Glasgow, interest on "Exhibition Fund,"	£49	7	5			
,, Interest from Bank, ...	6	14	4			
				56	1	9
,, Catalogues sold, 27, at 1s., ...	£1	7	0			
,, *Proceedings* sold, ...	0	13	4½			
				2	0	4½
				£867	6	2½

Cr.

1874. Oct. 31.						
By Salaries and Wages, ...				£172	13	10
,, New Books and Binding, ...				91	2	7
,, Printing *Proceedings*, Circulars, &c., ...				114	0	6
,, Postage and delivery of Circulars, &c., ...				26	8	10
,, Stationery, ...				8	8	3
,, Lithographing and Printing Plates for *Proceedings*, . .				41	5	3
,, Rents, ...				130	0	0
,, Insurance, Gas, Coal, Cleaning, &c., ...				26	16	3
,, Petty Charges and Sundries, ...				2	3	8½
,, Subscription to Ray Society, 1874, ...	£1	1	0			
,, ,, Palæontographical Society, 1874, .	1	1	0			
				2	2	0
,, Chemical Section.—Expenses per Treasurer of Section, . .				6	1	11
,, Sanitary Section.—Expenses per Secretary of Section, . .				4	7	6
,, Balances—						
In Union Bank, ...	£240	0	0			
In Treasurer's hands, ...	1	15	7			
				241	15	7
				£867	6	2½

Glasgow, *10th November, 1874*.—We, the Auditors appointed to examine the Treasurer's Accounts, have examined the same, of which the above is an Abstract, and found them correct, the Balance in Union Bank at 31st October last being Two hundred and forty pounds sterling; and in Treasurer's hands, One pound fifteen shillings and seven pence.

(Signed) GEORGE WATSON.
PETER W. DIXON.

The following Minute of the proceedings of Council, of date November 16, was read :—

"In accordance with the provision in Rule XIII., that 'vacancies occasioned in the Council by resignation or otherwise shall be filled up by the Council,' it was agreed, on the motion of Mr. Robertson, seconded by Mr. Rowan, to appoint Mr. Horatio K. Bromhead to succeed Dr. Thorpe, resigned, and occupy his place during the remaining year of the period for which he was elected ; and to appoint Mr. Sigismund Schuman to succeed Mr. Robert Gray, resigned, and to occupy his place during the two remaining years of the period for which he was elected."

The Society then proceeded to the election of Office-bearers, in room of those retiring by rotation.

On the motion of Professor Grant, Professor Sir William Thomson, LL.D., F.R.S., was elected to the office of President.

Professor Grant proposed that Dr. Wallace be elected to the office of Junior Vice-President, which was seconded by Mr. William M'Adam.

Mr. John M'Gavin proposed that Dr. Andrew Fergus be appointed to the office, which was seconded by Mr. Hugh Macbean.

The vote was taken by ballot, Mr. David Mackinlay and Mr. Edward A. Wünsch having consented to act as scrutineers of votes.

The scrutineers reported that 75 had voted for Dr. Fergus, and 26 for Dr. Wallace.

Dr. Fergus was then declared by the Chairman to have been duly elected Junior Vice-President.

On the motion of Professor Grant, Mr. St. John Vincent Day was re-elected Librarian, Mr. John Mann was re-elected Treasurer, and Mr. William Keddie was re-elected Secretary.

The following gentlemen were nominated to succeed the four Members of Council retiring by rotation, viz. :—

Professor James Thomson, LL.D., C.E., Professor Ferguson, M.A., Mr. William Dron, Mr. Alexander Scott, Dr. William Wallace, Mr. Edward A. Wünsch, and Mr. James Deas, C.E.

Mr. James Thomson, F.G.S., and Mr. David Mackinlay consented to act as scrutineers of votes.

The scrutineers reported that the following had the greatest number of votes, viz. :—Professor Ferguson, 78 ; Dr. Wallace, 76 ; Professor James Thomson, 69 ; Mr. Alexander Scott, 61.

These gentlemen were therefore declared by the Chairman to have been duly elected Members of Council.

On the motion of Dr. Fergus, the Society voted its warmest thanks

to Professor Grant for his valuable services during his term of office.

Professor Grant acknowledged the compliment, and remarked that it afforded him great pleasure to be succeeded as President by a distinguished colleague of his own, who had already held the office, and whose labours reflected so much lustre on the science of the nation.

Mr. W. Keddie read "Notes of a Visit to Niagara, &c., in the Summer of 1873."

December 2, 1874.—Dr. Fergus, *Vice-President, in the Chair.*

The following were elected members of the Society, viz.:—

Mr. William Ker, 1 Windsor Terrace, West; Mr. James Adams, Timber Merchant, 9 Royal Crescent; Mr. Albert Newhaus, Merchant, 1 Prince's Terrace, Dowanhill; Mr. Alexander Wilson, Hydepark Foundry, 54 Finnieston Street; Mr. Stewart Manford, Shipowner, 24 Oswald Street; Mr. John Brownlie, Grain Merchant, Whitehill Street; Mr. John Gourlay, C.A., 128 St. Vincent Street; Mr. John Davidson, Gas Manager, 13 Winton Terrace, Crosshill; Mr. George R. Murray, Manufacturing Chemist, Maryhill; Dr. Chr. Heinzerling, Assistant to Professor G. Bischof, Andersonian University.

The Council reported that it had taken into consideration the remit from the Society, of date November 4, to adopt whatever measure might be deemed necessary in connection with the Mitchell Bequest to this city for establishing a Public Library. The Council had accordingly appointed the following Committee to open a communication with the Magistrates and Town Council on the subject, and otherwise to act in the matter as they may see cause, viz.:—

Mr. James Cleland Burns, *Convener;* Mr. John Mayer, *Sub-Convener*; Mr. James Thomson, F.G.S., Councillor M'Bean, Councillor W. R. W. Smith, Mr. William M'Adam, Mr. Horatio K. Bromhead, A.R.I.B.A., Mr. St. John Vincent Day, C.E.

The following papers were read:—"On the Absence of Air and Water from the Moon," by Francis Napier, Esq., Ass. Inst. C.E. (Communicated by Mr. James R. Napier.) "Experiments on Fluid Jets and Induced Currents," by Mr. Alexander Morton.

December 16, 1874.—Dr. Fergus, *Vice-President, in the Chair.*

The Secretary read the following extract from a note received from Sir William Thomson:—"Allow me, through you, to thank the Society heartily for the great honour they have done me in electing me as President."

The following were elected members of the Society, viz.:—

Mr. William Douglas, 22 West Nile Street; Mr. James M. Fairlie, Chemist, 17 St. George's Road; Dr. James Patterson Cassells, 2 Newton Terrace; Mr. J. G. Reid, Carver, 37 St. Vincent Crescent; Mr. John Peters, Coppersmith, 29 South Shamrock Street.

The following papers were read:—"On an Apparatus for Testing the Lubricating Powers of various Liquids, shewing some hitherto unrecognised facts at variance with the commonly received laws of Friction," by R. D. Napier, Esq. "On the Effect of Loch Katrine Water on various Metals," by James R. Napier, Esq., F.R.S.

January 13, 1875.—Dr. Allen Thomson, *Vice-President, in the Chair.*

The following were elected members of the Society, viz.:—

Mr. Thomas Robertson Ogilvie, F.C.S., Joint Burgh Analyst, 19 Brisbane Street, Greenock; Mr. William Baird, Drysalter, 7 Hampden Terrace, Queen's Park; Mr. Alexander M'Coll, Shipowner, 247 Bath Street; Mr. D. M. Nelson, Gas Engineer, 135 Buchanan Street.

The Council proposed that the following gentlemen, who were formerly members, but whose connection with the Society ceased on their removing from the city, be appointed Corresponding Members, in accordance with Rule XI., which requires that they shall be proposed and balloted for in the same manner as ordinary members, viz.:—

Dr. James Bryce, M.A., F.G.S.; Rev. H. W. Crosskey, F.G.S.; Mr. Robert Gray, F.R.S.E.; Dr. Thomas E. Thorpe, F.R.S.E.; Mr. Alexander S. Herschel, B.A., F.R.A.S.

Mr. James Cleland Burns, Convener of the Committee of the Society on the Mitchell Library Bequest, reported that the Committee had an interview with the Magistrates and Town Council on

the 24th of December last, and urged upon them the adoption of the Public Libraries and Museums Act.

Dr. Robert Bell read a paper "On Contagion; what is it? and what is its mode of attack?"

The subject of the paper was discussed by Dr. Dougall, Dr. Cassels, Mr. J. Mayer, and Mr. Coleman.

January 27, 1875.—Dr. FERGUS, *Vice-President, in the Chair.*

The following were elected members of the Society, viz.:—

Mr. R. W. Henry, Manufacturer, 14 Garthland Street; Mr. William Turner, Iron Merchant, 33 Renfield Street; Mr. Hugh Laird, Jun., Agent, Clydesdale Bank, Argyle Street; Mr. Robert Pickering, 10 Albany Place; Mr. John Pickering, 5 Royal Crescent; Mr. John White, Scotstown and Shitmills, Partick; Mr. W. D. Mackenzie, Publisher, 43 Howard Street; Mr. George P. Weight, Civil Engineer, Clutha Ironworks; Mr. James Storer, 8 Annfield Place.

The following were elected Corresponding Members, viz.:—

Dr. James Bryce, M.A., F.G.S.; Rev. H. W. Crosskey, F.G.S.; Mr. Robert Gray, F.R.S.E.; Mr. Alexander S. Herschel, B.A., F.R.A.S.; Dr. Thomas E. Thorpe, F.R.S.E.

Dr. James Bryce read "Notes of a Tour in Germany, with Special Inquiry regarding the provisions for Scientific and Technical Education."

In the discussion of the paper the following took part:—Mr. Anderson, M.P., Mr. David Sandeman, Mr. John Mayer, Mr. Thomas Muir, Mr. Ross, Gartsherrie, Mr. John Donald, Mr. Wünsch, &c.

February 10, 1875.—Dr. FERGUS, *Vice-President, in the Chair.*

The following were elected members of the Society, viz.:—

Mr. Alexander M'Kinnon, 1 Holland Place; Mr. William M'Adam, Jun., 30 St. Vincent Crescent.

The following papers were read:—

"Outline of a Method for the Interpolation and Summation of Numerical Series," by Mr. John Donald, St. Rollox Schools.

"On Air and Water in Relation to Public Health," by Dr. William Wallace, F.R.S.E., F.C.S.

The discussion on Dr. Wallace's paper was adjourned till Wednesday, the 10th of March.

February 24, 1875.—Dr. FERGUS, *Vice-President, in the Chair.*

The following were elected members of the Society, viz.:—

Dr. John Weir, F.R.C.S.Edin., 26 Sandyford Place; Mr. Robert Duncan, Engineer, Partick Foundry; Mr. William Sheppard, Govan Colliery.

The following papers were read:—1. "On a Self-acting Railway Train Brake," by Mr. James Steel.

In the discussion of this paper, Dr. King, of Liverpool, Mr. Deas, Mr. W. Robertson, Mr. M'Gavin, Mr. Day, and Mr. Dron took part.

2. "On M'Kay's Tube-boring Tool," by Mr. William Dron.

Mr. Deas, Mr. J. P. Smith, and Mr. Menzies, of Newcastle, bore testimony to the practical usefulness of the invention.

March 10, 1875.—Dr. FERGUS, *Vice-President, in the Chair.*

The following were elected members of the Society, viz.:—

Professor George Buchanan, M.D., 193 Bath Street; Mr William Rodger, C.E., 131 Hope Street; Mr. James Steel, 302 St. Vincent Street; Mr. John Steven, 12 Walworth Terrace.

The Council proposed the election, as an Honorary Member, of William Froude, Esq., C.E., F.R.S., Chelston Cross, Torquay.

Mr. James R. Napier gave notice that at next meeting he would move "That a Petition from this Society be sent to Her Majesty Queen Victoria." (See minute of next meeting.)

The discussion on Dr. Wallace's paper "On Air and Water in Relation to Public Health," was commenced by Dr. R. Bell, who was succeeded by Dr. Gairdner, Mr. Alex. Scott, Mr. Jas. Mactear, Mr. Jas. Thomson, Mr. W. R. W. Smith, and Dr. Wallace.

Mr. Thomas Muir, Secretary to the Section of Physics, read a paper by Mr. James N. Miller "On the Trisection of an Angle."

Mr. James R. Napier read a paper by Mr. Andrew Crawford "On a Waste-Preventing Water-Supply Apparatus."

The discussion on the latter paper was adjourned till the meeting after the next.

March 24, 1875.—Dr. FERGUS, *Vice-President, in the Chair.*

The following were elected members of the Society, viz.:—

Mr. James Galbraith, M.A., LL.B., Writer, 66 Bath Street; Mr. Arthur D. Fordyce Culbard, 70 Miller Street.

It was moved by Dr. Fergus (in the absence of Sir William Thomson), seconded by Mr. James R. Napier, and unanimously agreed, that William Froude, Esq., C.E., F.R.S., Chelston Cross, Torquay, be elected an Honorary Member of the Society.

It was moved by Mr. James R. Napier, seconded by Mr. Deas, and unanimously agreed, that the following Petition be sent to Her Majesty Queen Victoria :—

"TO HER MOST GRACIOUS MAJESTY QUEEN VICTORIA.

"The HUMBLE PETITION of the PHILOSOPHICAL SOCIETY of GLASGOW,

"*Sheweth*, That the Members of the Philosophical Society of Glasgow, being persons engaged in the direction of Studies in the University of Glasgow, and in the Arts, Manufactures, Trade, and Commerce of the City, view with serious concern the calamitous loss of life and destruction of property on Railways from Collisions and other preventible causes.

"The Philosophical Society therefore prays that your Majesty would be pleased to direct that your Majesty's Commission, presided over by His Grace the Duke of Buckingham, and now taking evidence upon Accidents on Railways generally, should inquire into, and make an interim report upon, Continuous Brakes, laying down the conditions which such Mechanical Contrivances should be capable of fulfilling, with the view, if deemed advisable, to their compulsory use on the whole Railway System of the United Kingdom."

There was laid on the table the Council's Report on the Revision of the Rules of the Society, a copy of the same having been sent to each member.

Dr. Wallace gave notice that at the next meeting of the Society

he would move that the Rules, as amended by the Council, be adopted by the Society.

The Vice-President stated that the Council having been repeatedly solicited by members of the Society to recommend a change in the day of meeting, it would be observed that in the draft of Amended Rules the Council had submitted, alternatively, Tuesday and Wednesday. The Vice-President invited a general expression of opinion on this point by the members of the Society.

Mr. Nathaniel Dunlop proposed that in the circular calling the meeting for the discussion of the Rules, the members who are unable to attend be requested to express their opinion, in a note to the Secretary, as to the propriety of changing the night of the Society's meeting from Wednesday to Tuesday.—Agreed.

Mr. John Mayer suggested that the Committee on Patents for Inventions, appointed by the Society in 1869, should be called together to take into consideration the Lord Chancellor's Bill now before Parliament.

Mr. Day having offered some remarks on the importance and urgency of the subject,

The Society agreed to instruct the Committee to watch over the measure in question, and appointed the following gentlemen to fill the vacancies in the Committee occasioned by death or removal, viz.:—Mr. James R. Napier, Dr. Wallace, Mr. J. M'Gavin, Mr. W. M'Adam, Mr. W. Dron, Mr. Day, Mr. J. J. Coleman. Mr. Mayer to be Sub-Convener.

Mr. James T. Bottomley, in the unavoidable absence in London of Sir William Thomson, read a paper "On the Mathematical Theory of the Rolling Error of the Compass." He afterwards explained Sir William Thomson's Tide-Calculating Machine and Improved Tide Gauge.

Mr. Bottomley received the thanks of the Society.

April 14, 1875.—Dr. FERGUS, *Vice-President, in the Chair.*

The following were elected members of the Society, viz.:—

Mr. George R. Morrison, 10 Belgrave Terrace, Hillhead; Mr. James Marshall, Sunnyside, Partick Hill; Mr. John Stewart, Dyer, 29 Napiershall Street.

A letter was received from Mr. Froude expressing his thanks for the honour the Society had conferred on him by electing him an Honorary Member.

Mr. John Mayer, Sub-Convener of the Committee appointed on the 24th March, to consider the Lord Chancellor's Bill presently before Parliament, with reference to Patents for Inventions, reported that the Committee had met, and agreed to the following form of Petition to the House of Commons :—

"*Unto the* HONOURABLE *the* COMMONS *of the* UNITED KINGDOM *of* "GREAT BRITAIN *and* IRELAND *in Parliament assembled.*

"The HUMBLE PETITION of the PHILOSOPHICAL SOCIETY of GLASGOW,

"*Sheweth,* That the Philosophical Society of Glasgow, consisting of upwards of 600 Members, being persons engaged in the Arts, Manufactures, Trade, and Commerce of the City, views with serious concern several of the provisions of a Bill now before your Honourable House, intituled, 'An Act for Consolidating, with Amendments, the Acts relating to Letters Patent for Inventions.'

"That the Society feels assured that were the Bill as amended in the House of Lords to become law, it would greatly discourage those persons who devote their time, talents, and capital to the production and development of useful inventions, and would in every sense prove a grievous wrong and injury to all classes of society.

"That the Society is satisfied that more and greater benefits are conferred upon the country under the existing Patent Laws than would be the case were the Bill now before your Honourable House to pass into law.

"Your Petitioners, therefore, humbly pray your Honourable House that the said Bill may not pass into law."

The form of Petition was approved of by the Society.

The discussion on Mr. Andrew Crawford's "Waste-preventing Water-supply Apparatus," adjourned on the 10th of March to the present meeting, was introduced by Mr. James R. Napier, who was followed by Mr. John Jex Long, Mr. William M'Adam, Mr. John Taylor, Jun., Mr. W. R. W. Smith, and Mr. Dron; Mr. Crawford closing the discussion with a reply.

Dr. Wallace then moved that the Rules, as amended by the Council, be adopted by the Society.

The Secretary reported that six letters had been received from members in favour of changing the day of the Society's meeting from Wednesday to Tuesday, and one in favour of its continuing to meet on Wednesday.

It was moved by Mr. N. Dunlop, and seconded by Mr. Currie Gregory, that the day of meeting be changed from Wednesday to Tuesday.

It was moved by Mr. John Mayer, and seconded by Mr. John Jex Long, that the Society continue as heretofore to meet on Wednesday.

The two motions having been put to the vote, 15 voted for changing the day from Wednesday to Tuesday, and 23 for continuing to meet on Wednesday.

The Rules, as revised by the Council, were read and considered *seriatim*, and several emendations were introduced.

The Council, at a meeting held this evening, having, by a majority, agreed to recommend that Presidents of Sections be included as constituent members of Council (*ex-officio* and if otherwise eligible), the Society approved of this proposal.

The draft of Rules, as amended by the Society, was then formally approved of by a first vote, the second reading being fixed for next meeting.

April 28, 1875.—Dr. Fergus, *Vice-President, in the Chair.*

Mr. Morris Pollok, 12 Park Terrace, was elected a member of the Society.

The following were proposed as members of the Society, viz. :—

Mr. Taylor Shipley Hunter, Stobcross New Dock Works; recommended by Mr. St. John Vincent Day, Dr. Fergus, and Mr. A. Robertson. Mr. Robert Young, 136 St. Vincent Street; recommended by Mr. Alexander Scott, Dr. Fergus, and Mr. John Jex Long. Mr. Andrew Crawford, Plumber, 339 Dumbarton Road; recommended by Mr. Alexander Scott, Dr. Fergus, and Mr. James R. Napier. Mr. James Stewart, Sanitary Engineer, 4 South Portland Street; recommended by Mr. George Richardson, Mr. W. R. W. Smith, and Mr. A. Robertson. Mr. William Jacks, Messrs. Robinows & Marjoribanks; recommended by Mr. William Turner, Mr. St. John Vincent Day, and Mr. Andrew Symington.

[To be balloted for at the opening meeting of next Session.]

Letters were read from Mr. George Anderson, M.P., acknow-

ledging receipt of the Society's Petition to the Queen on the subject of Railway Accidents, which he had transmitted to the Home Secretary for presentation; and of the Society's Petition to the House of Commons against the Lord Chancellor's Bill on Patents, which Mr. Anderson mentioned he had presented.

The following Report was received from Mr. Tatlock, Secretary to the Chemical Section:—

REPORT OF THE CHEMICAL SECTION.

THE Council of the Section have much pleasure in reporting that the past Session has been an eminently successful one.

The following papers were read during the Session:—"On the Estimation of Phosphoric Acid," by E. M. Dixon, B.Sc.; "On the Estimation of Phosphoric Acid," by Thomas R. Ogilvie, F.C.S.; "On Flue-testing," by James Mactear; "On the presence of Lead and Copper in Aerated Waters," by Dr. James Milne; "On some Mechanical Appliances for facilitating Chemical Operations," by W. L. Rennoldson; "On the determination of Phosphoric Acid in presence of a large excess of Citric Acid," by E. M. Dixon, B.Sc.; "On the Spontaneous Combustion of Coal, and the great Loss of Coal-laden Ships," by John Mayer, F.C.S.; "On the Adulteration of Food, Drink, and Drugs Bill," by Dr. John Clark; "On the Methods in use for Testing Petroleum Oils," by J. J. Coleman, F.C.S.; "On Nitrification and on the Filtration of Sewage through Certain Media," by E. C. C. Stanford, F.C.S., *President*; "On the Filtration of Sewage through Spent Oil Shale," by J. J. Coleman, F.C.S.; "On the Chemistry of Sugar Refining," by G. C. Stewart, F.C.S.

Most of these papers were the records of original research, and several of them were the fruit of laborious investigation.

As the result of a representation made originally by the Section, and supported by the Newcastle Chemical Society, the British Association have appointed a Committee, with a grant of £10, to investigate the methods in use for the analysis of some commercial products, particularly Manures and Potash Salts.

At the request of the Section the Council of the Society has kindly granted £4 to be invested in Apparatus for the investigation of the subject of "Nitrification," with a view to the settlement of the question, whether the nitrogen of the air is converted into nitric acid by oxidation.

During the Session seven associates have been enrolled.

Mr. Gavin Irving Dickson, Secretary to the Sanitary and Social Economy Section, read the following

Report of the Sanitary and Social Economy Section.

The Council have the pleasure of reporting another active Session.

The following is an abstract of the different subjects brought before the Section, viz.:—

1st Meeting.—"On the Nature and Origin of Zymotic Diseases." By Mr. John Dougall, M.D., Medical Officer of the Burgh of Kinning Park.

2nd Meeting.—Inaugural Address by the new President, Mr. W. R. W. Smith, dealing with the Sewage Question, as brought under review of the Section since its commencement.

3rd Meeting.—"On the Immediate Results of the Proceedings of the City of Glasgow Improvement Trust since Whitsunday last, as regards the Inhabitants displaced thereby." By Mr. James B. Russell, M.D., Health Officer of the City.

4th Meeting.—1st. "On the Excessive Mortality of Glasgow—its Causes and Remedies." By Mr. Matthew Charteris, M.D.

2nd. Consideration of a Communication as to contemplated changes in the Laws of the Society, from the Revision Committee appointed by General Council, per Mr. Alexander Scott.

5th Meeting.—1st. "Scheme for intercepting and utilising the Sewage of Towns, and Preventing the Pollution of Rivers." By Mr. James M'Intyre, Port-Glasgow.

2nd. "Production of Model and description of Self-acting Machine for separating and utilising the Sewage of Glasgow." By Mr. D. A. B. Murray, Glasgow.

3rd. "Explanation of his Self-acting Sewage Gas-trap." By Mr. W. P. Buchan, Glasgow.

6th Meeting.—"On Surface Removal of City Refuse—the Key to Public Health." By Mr. Charles Elcock, Secretary of the Universal Charcoal and Sewage Company (Limited), Manchester.

7th Meeting.—"On purifying and utilising the Drainage, &c., of Cities, in reference to the present Panic at Crosshill, with Exhibition of Model of Machine and relative plans," &c. By Mr. Thomas Short, Glasgow.

8th Meeting.—1st. "On the Total Abolition of the Excise Duty on Spirituous Liquors—a Necessity—in order to secure an Efficient Temperance Reformation." By Councillor James Durham, Edinburgh.

2nd. Report by the Council on the Section's proceedings during the Session.

The number of the Section's Associates is now thirty-five, shewing a slight increase since last Session.

The different meetings have been all well attended by the members and associates of the Society, and the full reports given by the newspapers of the proceedings must have added considerably to their general usefulness.

The Council of the Section is presently composed as follows :—

W. R. W. Smith, Esq., *President.*
James B. Russell, Esq., M.D., *Vice-President.*
Alexander Scott, Esq., *Vice-President.*

Ordinary Members.

Mr. Arthur Herriot.	Mr. Kenneth M. M'Leod.
Mr. William Melvin.	Mr. Andrew Fergus, M.D.
Mr. Stephen Mason.	Mr. John Dougall, M.D.
Mr. William M'Adam.	Mr. Nathaniel Dunlop.

Mr. Robert Renfrew, M.D.

Mr. Gavin Irving Dickson, *Secretary.*

Mr. Thomas Muir, Secretary to the Physical Section, read the following

Report of the Section of Physics, including Mechanics and Engineering.

The Council of the Physical Section report with pleasure that the Section has enjoyed during the past winter an amount of success scarcely to have been expected on the first Session of its existence. The main object of the Section has been to secure papers containing the results of original thought or investigation, and yet vested with such general interest as might warrant their being read with profit to the Society at large. The number of papers offered has been exceedingly encouraging, there being as many, indeed, as could be satisfactorily dealt with in the course of the Session. Of these the Council approved of the fourteen following, which were judged satisfactory in regard to the first condition of originality, and which are now known to have acquitted themselves on the second head, viz., acceptability in the matter of general interest to the Society :—

1. "On the Absence of Air and Water from the Moon." By Mr. Francis Napier, Ass. Inst. C.E.

2. "Experiments on Fluid Jets and Induced Currents." By Mr. Alexander Morton.

3. "On an Apparatus for Testing the Lubricating Power of various Liquids, shewing some hitherto unrecognised facts at variance with the commonly received Laws of Friction." By Mr. R. D. Napier.

4. "On the Effect of Loch Katrine Water on various Metals." By Mr. James R. Napier, F.R.S.

5. "On a Self-acting Railway Train Brake." By Mr. James Steel.

6. "On M'Kay's Tube-Plate Boring Tool." By Mr. William Dron.

7. "On a Waste-preventing Water-supply Apparatus." By Mr. Andrew Crawford.

8. "On the Trisection of an Angle." By Mr. James N. Miller.

9. "On the Mathematical Theory of the Rolling Error of the Compass." By Sir Wm. Thomson, LL.D.

10. "On the High Antiquity of Iron and Steel." By Mr. St. John V. Day, F.R.S.E.

11. "Note of Experiments with Giroud's Rheometer." By Mr. William Foulis.

12. "On some Fractured Rivets from a Steam Boiler." By Mr. James R. Napier.

13. Mr. James R. Napier shewed a method of "Spinning Tops without a Handle."

14. "On the Conical Filter of Greatest Capacity for a Given Slant Height or Radius of Filter Paper." By Mr. James R. Napier.

During the Session six associates have been elected; and the Council confidently hope that members appreciating the work which has been done will aid them in greatly adding to this number in the Sessions to come.

The Amended Rules of the Society were, on the suggestion of the Chairman, held as read a second time, and unanimously adopted as the Constitution of the Society.

Mr. St. John Vincent Day read "A Third Communication on the High Antiquity of Iron and Steel."

Dr. Wallace described Phibbs' Patented Process for the Ageing of Whisky and other Spirits, and exhibited a Model of the Apparatus.

Dr. Wallace adduced "A striking illustration of the Germ Theory of Putrefaction." (See *Proceedings.*)

Mr. James R. Napier exhibited some Fractured Rivets from a Steam Boiler. He also shewed a method of Spinning Tops without a handle.

Mr. T. Muir read "Note of Experiments with Giroud's Rheometer," by Mr. Foulis.

The Chairman, on announcing that this was the closing meeting of the Session, congratulated the Society on the variety and importance of its proceedings, adding that the new and vigorous Physical Section had very materially contributed to the interest of the Session.

On the motion of Dr. Wallace, the Society voted its cordial thanks to Dr. Fergus, Vice-President, for the able manner in which he had officiated as Chairman throughout the Session.

ADDITIONS TO THE LIBRARY.

Donations.	Presented by	
Transactions of the Odontological Society of Great Britain, . . .	The Society.	3 Vols.
Transactions of the Odontological Society of Great Britain, . . .	The Society.	3 Parts.
Proceedings of the Literary and Philosophical Society of Liverpool, . .	The Society.	1 Part.
Proceedings of the Bristol Naturalists' Society, ...	The Society.	1 ,,
Memoires de la Société des Sciences de Bordeaux, ...	The Society.	2 ,,
Journal of the Franklin Institute, .	The Institute.	8 ,,
Proceedings of the Geological Society of London, 1838, ...	Dr. Bryce.	1 Vol.
Proceedings of the Geological Society of London, 1842, ...	,,	1 ,,
Journal of the Geological Society of London for 1842-45, . . .	,,	1 ,,
Statistique de l'Industrie a Paris resultant de l'Enquête faite par la Chambre de Commerce, pour les Années 1847-48. 4to. Paris, 1851,	,,	1 ,,
On the Geology of Clydesdale. (No date.)	,,	1 ,,
Manufacturing Arts in Ancient Times, with Special Reference to Bible History. By James Napier, F.R.S.E., F.C.S. 8vo. London, 1874, . .	James Napier.	1 ,,
Transactions of the National Association for the Promotion of Social Science. London, 1860–1863, and 1865–1873, ...	The Association.	12 ,,
Prisons and Reformatories at Home and Abroad: being the Transactions of the International Penitentiary Congress held in London, July 3rd to 13th, 1872. Edited, at the request of the International Committee, by Edwin Pears, LL.B. 8vo. London, 1872, ...	James Robinson.	1 ,,

Donations.	Presented by	
Verhandelingen der Koninklijke Akademie van Wetenschappen, 1874, .	Amsterdam Society.	1 Part.
Jaarboek van de Koninklijke Akademie van Wetenschappen, 1873, . .	,,	1 ,,
Verslagen en Mededeelingen der Koninklijke Akademie van Wetenschappen, 1874, ...	,,	2 Vols.
Processen Verbaal Koninklijke Akademie van Wetenschappen te Amsterdam, 1873–74, ...	,,	1 Part.
Archives Néerlandaises des Sciences Exactes et Naturelles, Publiées par la Société Hollandaise des Sciences a Harlem. Par E. H. von Baumhauer,	J. J. Enschedé.	2 Parts.
Révision des Espèces Insulindiennes de la Famille des Synancéoïdes. Par P. Bleeker. Harlem, 1874, . . .	,,	,,
Proceedings of the Royal Society of Edinburgh, ...	The Society.	1 Part.
Transactions of the Botanical Society of Edinburgh, ...	The Society.	1 ,,
Transactions and Proceedings of the New Zealand Institute for 1873, .	James Hector, M.D.	1 Vol.
Proceedings of the American Academy of Arts and Science, . . .	The Academy.	2 ,,
Proceedings and Transactions of the Royal Society of Victoria, 1874, .	The Society.	1 ,,
Proceedings of the Society of Biblical Archæology, ...	The Society.	2 ,,
Proceedings of the Boston Society of Natural History, ...	The Society.	4 ,,
Proceedings of the Lyceum of Natural History in the City of New York, .	The Lyceum.	8 ,,
Proceedings of the Bristol Naturalists' Society, ...	The Society.	8 ,,
Experiments with Safety Lamps, .	W. Galloway.	1 Pamphlet.
On the Connection between Colliery Explosions and Weather in 1872, .	,,	1 ,,
Progress of Meteoric Astronomy in 1874, ...	A. S. Herschel.	1 ,,
On the Spectrum of the Aurora, . .	,,	1 ,,
On the Physical Cause of the Submergence and Emergence of the Land during the Glacial Epoch. 1874, .	James Croll.	1 ,,
On Subaërial Denudation, and on Cliffs and Escarpments of the Chalk and the Lower Tertiary Beds, . .	W. Whittaker, B.A.	1 ,,
Committee on the Treatment and		

DONATIONS.	Presented by	
Utilisation of Sewage, reappointed at Brighton, 1872, ...	The Committee.	1 Pamphlet.
La Terre, Description des Phénoménes de la Vie du Globe. Par Elisée Beclus. 8vo. Paris, 1869, . .	W. Collins, Esq.	1 Vol.
Synopsis of the Flora of Colorado. By .Thomas C. Porter and John M. Coulter. 8vo. Washington, 1874, .	U. S. Survey.	2 Vols.
Report of Explorations in 1873 of the Colorado of the West and its Tributaries. By Professor J. W. Powell,	J. W. Powell.	1 Pamphlet.
On the Natural History and Distribution of Yellow Fever in the United States, from A.D. 1668 to A.D. 1874. By J. M. Toner, M.D. Washington,	J. M. Toner, M.D.	1 ,,
Bulletin of the Buffalo Society of Natural Sciences, ...	The Society.	2 Parts.
Memoirs of the Boston Society of Natural History, ...	The Society.	3 ,,
Canadian Entomologist, . . .	E. B. Reed.	9 ,,
Abstract of the Proceedings of the Liverpool Geological Society, . .	The Society.	1 ,,
Annual Report of the Commissioner of Agriculture and Public Works for the Province of Ontario on Agriculture and Arts, for the year 1873. 8vo. Toronto, 1874, ...	E. B. Reed.	1 Vol.
Popular Treatise on the Patent Laws and their Working and Reform, for the Development of Arts and Manufactures and the Protection of Inventors. By John Brown. 1874, .	John Brown.	1 Pamphlet.
Journal of the Associations of Foremen Engineers and Draughtsmen, . .	The Associations.	9 Parts.
Canadian Institute, ...	The Institute.	4 ,,
Abridgments of Specifications relating to Patents for Inventions, . .	B. Woodcroft.	14 Vols.
Chronological and Descriptive Index of Patents Applied for and Patents Granted, ...	,,	8 ,,
Recent Objections to the Origination of Gentile Measures by the Great Pyramid, ...	St. John V. Day.	1 Pamphlet.
Preliminary Notice of some Facts (heretofore unperceived) which will be shewn to aggregate into certain Cosmic and Metric Systems in the Great Pyramid. London, 1874, .	,,	1 ,,

Donations.	Presented by	
Transactions of the North of England Institute of Mining and Mechanical Engineers. Vol. 23. 1873-74,	Theo. Wood Bunning.	1 Vol.
Proceedings of the California Academy of Sciences,	A. Kellogg.	2 Parts.
Census of Victoria for 1871,	H. H. Hayter.	1 Part.
Statistics of the Colony of Victoria,	,,	6 Parts.
Statistics of the Colony of Victoria for 1873,	,,	1 Part.
Australasian Statistics for 1873,	,,	1 ,,
Report of City of Glasgow Sanitary Inspector on River Clyde Pollution, 1872-74,	K. M'Leod.	1 ,,
Greenwich Observations, Astronomical, Magnetical, and Meteorological Observations for 1872,	Greenwich Observatory.	
Greenwich Magnetical and Meteorological Results for 1872,	,,	
Results of Astronomical Observations, made at the Royal Observatory, for 1872,	,,	
Cape of Good Hope; 1159 Stars, 1856-1861, Reduced to the Epoch 1860,	,,	
Memoirs of the Royal Astronomical Society for 1874-75,	,,	
Canada: Past, Present, and Future; being an Historical, Geographical, Geological, and Statistical Account of Canada West. By W. H. Smith. 8vo. Toronto,	Dr. Bryce.	2 Vols.
Statistics of New Zealand for 1872,	,,	1 ,,
Mémoires de la Société de Sciences de Bordeaux,	The Society.	1 Part.
Mémoires de la Société Royale des Sciences de Liége. Bruxelles, 1873,	The Society.	1 Vol.
Annuaire de l'Academie Royale, 1874, Bruxelles,	A. Quetelet.	1 ,,
Bulletins de l'Academie,	,,	2 ,,
Annales Meteorologiques, 1872-73,	,,	2 Parts.
Annual Report of the Board of Regents of the Smithsonian Institution for 1872,	The Institution.	1 Vol.
Results Derived from an Examination of the United States War Maps for 1872 and 1873,	E. Loomis, Esq.	1 Pamphlet.
Leeds Philosophical and Literary Society: The Annual Report, 1873-74,	The Society.	1 Part.

DONATIONS.	Presented by	
Monthly Notices of the Royal Astronomical Society, ...	..	12 Parts.
Archives du Musée Teyler. . . .	J. J. Enschedé.	3 Vols.
Indexes for Patents and Patentees. Victoria, 1872.	W. H. Archer.	2 ..
Reformatory Prison Discipline, as Developed by the Rt. Hon. Sir Walter Crofton, in the Irish Convict Prisons. By Mary Carpenter. 12mo. London. 1872.	James Robinson.	1 Vol.
Lectures on Economic Science: Delivered under the Auspices of the Committee on Labour and Capital, appointed by the National Association for the Promotion of Social Science. 12mo. London, 1870.	..	1 Vol.
Théorie et Application de l'Impot sur le Capital. Par Menier. 8vo. Paris, 1874, ...	..	1 Vol.
Working Classes. By Chas. Lamport. F.S.S. London. 1874. . . .	..	1 Pamphlet.
Proceedings of the Berwickshire Naturalists' Club.	The Club.	1 Part.
Proceedings of the American Philosophical Society.	The Society.	2 Parts.
Proceedings of the Academy of Natural Science. Philadelphia. . . .	The Academy.	3 ..
Proceedings of the South Wales Institute of Engineers, ...	The Institute.	2 ..
Proceedings of the American Philosophical Society.	The Society.	1 Part.
Proceedings of the American Pharmaceutical Association, ...	The Association.	1 Vol.
Proceedings of the Bath Natural History and Antiquarian Field Club. .	The Club.	1 Part.
Astronomical and Meteorological Observations made during the Year 1871 at the U.S. Naval Observatory. .	B. F. Sands, Esq.	1 Vol.
Transactions of the Historic Society of Lancashire and Cheshire, . . .	The Society.	1 Vol.
Transactions of the Society of Engineers for 1872 and 1873, ...	The Society.	2 Vols.
Transactions of the Institution of Engineers and Shipbuilders in Scotland, ...	The Institution.	1 Vol.
Journal of the Statistical Society and General Index. Vols. 26 to 35, .	The Society.	3 Parts.
Journal of the Anthropological Institute of Great Britain and Ireland, . .	The Institute.	2 ..

The Philosophical Society's Exchanges with other Societies, &c.

Academy of Science,	Missouri.
Academy of Science,	Philadelphia.
American Academy,	Boston.
American Philosophical Society,	Philadelphia.
American Institute,	New York.
Boston Natural History Society,	Boston.
Berwickshire Naturalists' Club,	Alnwick.
Canadian Institute,	Canada.
California Academy,	California.
Commissioners of Patents,	Washington.
Franklin Institute,	Philadelphia.
Geological Survey Office,	Calcutta.
Historic Society,	Quebec.
Institution of Mechanical Engineers,	Birmingham.
Lyceum of Natural History,	New York.
Midland Institute of Mining Engineers,	Barnsley.
North of England Institute of Mining Engineers,	Newcastle-on-Tyne.
Natural History Society,	Portland, Maine.
New York Agricultural Society,	New York.
National Academy,	Washington.
Pharmaceutical Society,	Philadelphia.
Professor J. D. Dana,	Connecticut.
Professor E. Loomis,	Connecticut.
Professor J. Henry—National Observatory,	Washington.
Royal Academy of Science,	Berlin.
Royal Academy of Science,	Stockholm.
Royal Academy of Science,	St. Louis.
Royal Academy of Science,	Brussels.
Royal Academy of Science,	Amsterdam.
Royal Society of Victoria,	Melbourne.
Royal Institute of Lombardy,	Milan.
Royal Geographical Society,	Vienna.
Royal Institution of Cornwall,	Truro.
Smithsonian Institution,	Washington.
Society of Physical Science,	Bordeaux.
United States Observatory,	Washington.
United States Survey,	Washington.
University of Christiania,	Christiania.
J. Hoüel—La Société des Sciences Physique et Naturelles,	Bordeaux.
William H. Archer, Registrar-General,	Melbourne.
C. J. Matthes, of the Royal Academy,	Amsterdam.
E. B. Reed, Barrister-at Law, London,	Ontario.

W. R. Cooper, Secretary of the Society of Biblical Archæology,	London.
Alfred [illegible]—Entomological Society,	London.
James Hector, M.D.—New Zealand Institute,	New Zealand.
Alfred Brown—Literary and Philosophical Society,	Liverpool.
Dr. [illegible] M. Currie—Orleans County Society of Natural Sciences,	Vermont.
Charles Gilbert, Publisher of "Engineering,"	London.
[illegible] W. [illegible], Royal Institute of British Architects,	London.
Scottish Meteorological Society,	Edinburgh.
Botanical Society of Edinburgh,	Edinburgh.
Royal Society of Edinburgh,	Edinburgh.
Royal Physical Society of Edinburgh,	Edinburgh.
Royal Scottish Society of Arts,	Edinburgh.
Royal Society of London,	London.
Chemical Society,	London.
Society of Arts,	London.
Pharmaceutical Society,	London.
Photographic Society,	London.
Statistical Society,	London.
Royal Institution of Great Britain,	London.
Anthropological Society,	London.
Historic Society of Lancashire and Cheshire,	Liverpool.
Geological Society of Liverpool,	Liverpool.
South Wales Institute of Engineers,	Swansea.
Philosophical Society of Cambridge,	Cambridge.
Literary and Philosophical Society of Manchester,	Manchester.
Royal Cornwall Polytechnic Society,	Falmouth.
Cleveland Institution of Engineers,	Middlesborough.
Literary and Philosophical Society of Leeds,	Leeds.
Au Bureau Scientifique Central Neerlandais,	Harlem.
Robert L. J. Ellery, Astronomer-Royal,	Melbourne.
Bristol Naturalist's Club,	Bristol.

BOOKS BOUGHT.

L'Inde des Rajahs: Voyage dans l'Inde Centrale et dans les Présidences [illegible] *Bombay et du Bengale*. Par Louis Rousselet. Ouvrage contenant 3[illegible] *Gravures sur Bois, dessinées par nos plus Célèbres Artistes, et Six Cart*[illegible] *4to*. Paris, 1875.

Saskatchewan and the Rocky Mountains: A Diary and Narrative of Trav[illegible] *Sport, and Adventure, during a Journey through the Hudson's Bay Co*[illegible] *pany's Territories in 1859 and 1860*. By the Earl of Southesk, K.T[illegible] *F.R.G.S.* With Maps and Illustrations. 8vo. Edinburgh, 1875.

Grave-Mounds and their Contents: A Manual of Archæology, as exemplifi[illegible] *in the Burials of the Celtic, the Romano-British, and the Anglo-Saxo*[illegible] *Periods*. By Llewellynn Jewitt, F.S.A., &c. 1 vol. 8vo. London, 187[illegible]

Evolution and the Origin of Life. By H. Charlton Bastian, M.A., M.D[illegible] *F.R.S.* 12mo. London, 1874.

Arctic Experiences; containing Captain George E. Tyson's Wonderful Drift on the Ice-floe, a History of the "Polaris" Expedition, the Cruise of the "Tigress," and Rescue of the "Polaris" Survivors; to which is added a General Arctic Chronology. Edited by E. Vale Blake. 8vo. London, 1874.

Meeting the Sun: A Journey all Round the World, through Egypt, China, Japan, and California, including an Account of the Marriage Ceremonies of the Emperor of China. By William Simpson, F.R.G.S. 8vo. London, 1874.

Journal of the Royal Agricultural Society of England. Parts 1st and 2nd of Vol. 9.

Cave-Hunting: Researches on the Evidence of Caves respecting the Early Inhabitants of Europe. By W. Boyd Dawkins, M.A., F.R.S., F.G.S., F.S.A. 1 Vol. 8vo. London, 1874.

Assyrian Discoveries: An Account of Explorations and Discoveries on the Site of Nineveh, during 1873 and 1874. By George Smith, of the Department of Oriental Antiquities, British Museum; Author of "History of Assurbanipal," &c. 8vo. London, 1875.

Monograph of the Collembola and Thysanura. By Sir John Lubbock, Bart., M.P. 8vo. London, 1873.

Monograph of the British Annelids. Two Parts. Nemerteans. By W. C. M'Intosh, M.D., F.R.S.E., F.L.S., &c. London, 1873 and 1874.

Monograph of the British Spongiadæ. By J. S. Bowerbank, LL.D., F.R.S., F.L.S., F.G.S., F.Z.S., F.R.A.S. Vol. 3rd. London, 1874.

Principles of Mechanics, and their Application to Prime Movers, Naval Architecture, Iron Bridges, Water Supply, &c. By W. J. Millar, C.E. 12mo. London, 1874.

Records of the Past: being English Translations of the Assyrian and Egyptian Monuments. 3 Vols. 12mo. London.

Through Fanteeland to Coomassie: A Diary of the Ashantee Expedition. By Frederick Boyle. 8vo. London, 1874.

Lectures on the Early History of Institutions. By Sir Henry Sumner Main, K.C.S.I., LL.D., F.R.S. 8vo. London, 1875.

Annales du Conservatoire des Arts et Métiers. Parts 37 and 38 of Vol. 10.

Spon's Dictionary of Engineering, Civil, Mechanical, Military, and Naval, with Technical Terms in French, German, Italian, and Spanish. Edited by Byrne Spon. 3 Vols. Royal. London, 1873.

Life of Richard Trevithick, with an Account of his Inventions. By Francis Trevithick, C.E. 2 Vols. 8vo. London, 1872.

Deep-sea Fishing and Fishing Boats: An Account of the Practical Working of the Various Fisheries around the British Islands, with Illustrations and Descriptions of the Boats, Nets, and other Gear in use. By Edmund W. H. Holdsworth, F.L.S., F.Z.S., &c. 8vo. London, 1874.

Last Journals of David Livingstone, in Central Africa, from 1865 to his Death. Continued by a Narrative of his last Moments and Sufferings, obtained from his faithful servants, Chuma and Susi. By Rev. Horace Waller, F.R.G.S. 2 vols. 8vo. London, 1874.

History of the Intellectual Development of Europe. By John William Draper, M.D., LL.D. 8vo. London, 1863.

Language: Its Origin and Development. By T. Hewitt Key, M.A., F.I
8vo. 1874.

Scientific London. By Bernard H. Becker. 12mo. 1874.

Ceramic Art in Remote Ages; with Essays on the Symbols of the Circle,
Cross and Circle, the Circle and Ray Ornament, the Fylfot, and
Serpent, shewing their relation to the Primitive Forms of Solar
Nature Worship. By J. B. Waring. London, 1874.

Telegraph and Travel: A Narrative of the Formation and Developmen
Telegraphic Communication between England and India, under the Or
of Her Majesty's Government, with Incidental Notices of the Count
Traversed by the Lines. By Colonel Sir Frederic John Goldsmid, C
K.C.S.I. 8vo. London, 1874.

A Practical Handbook of Dyeing and Calico-Printing. By William Croo
F.R.S., &c. 8vo. London, 1874.

Amazon and Madeira Rivers. Sketches and Descriptions from the Note-b
of an Explorer. By Franz Keller. London, 1874.

Jottings during the Cruise of H.M.S. "Curaçoa" among the South Sea Island
1865. By Julius L. Brenchley, M.A., F.R.G.S. 8vo. London, 1873.

Coomassie and Magdala: The Story of Two British Campaigns in Africa.
Henry M. Stanley. 8vo. 1874.

Ismailia. A Narrative of the Expedition to Central Africa for the Suppres
of the Slave Trade, Organised by Ismail, Khedive of Egypt. By Sir Sa
W. Baker, Pacha, M.A., F.R.., F.R.G.S. 2 vols. 8vo. London, 18

Problems of Life and Mind. First Series: The Foundations of a Creed.
George Henry Lewis. 8vo, 2nd vol. London, 1875.

Principles of Science: A Treatise on Logic and Scientific Method. By
Stanley Jevons, M.A., F.R.S. 2 vols., 8vo. London, 1874.

Birds of Shetland, with Observations on their Habits, Migration, and Occasi
Appearance. By Henry Saxby, L.M.D. Edited by his Brother, Ste
H. Saxby, M.A. 8vo. Edinburgh, 1874.

The German Arctic Expedition of 1869-70, and Narrative of the Wreck of
"Hansa" in the Ice. 8vo. London, 1874.

Traité de Mécanique Générale, comprenant les Leçons Professées a l'E
Polytechnique. Par H. Resal. 2 vols. 8vo. Paris, 1873-74.

Essai sur une manière de Representer les Quantités Imaginaires dans les C
structions Géométriques. Par R. Argand. 8vo. Paris, 1874.

Spectres Lumineux. Par M. Lecocq de Boisbaudran. 2 vols. Text and Pl
Paris, 1874.

Universal Review of Mining, Metallurgy, Public Works, Science, and
Industrial Arts. 3 Parts.

Introduction to the Science of Religion. Four Lectures delivered at the R
Institution, with Two Essays on False Analogies and the Philosoph
Mythology. By F. Max Müller, M.A. 8vo. London, 1873.

Insects Abroad; being a Popular Account of Foreign Insects, their Struct
Habits, and Transformations. By the Rev. J. G. Wood, M.A., F.L
&c. 8vo. London, 1874.

Coal-Fields of Great Britain; their History, Structure, and Resources, w
Notices of the Coal-Fields of other Parts of the World. By Edward H
M.A., F.R.S. 8vo. London, 1873.

Bulletin de la Société Géologique de France, 1871-72. 8vo. Paris, 1872.

Tractat om Skepps-Byggeriet, tillika med Forklaring och Bevis ofver Architectura Navalis Mercatoria, &c. Genom Fredrich Hindr: af Chapman, 4to. Stockholm, 1775.

Théorie Eléméntaire des Phénomenes que présentent le Gyroscope, la Tupieo et le Projectile Oblong. Par E. Jouffret. Pamphlet. Paris, 1874.

Spectrum Analysis, in its Application to Terrestrial Substances and the Physical Constitution of the Heavenly Bodies. Familiarly explained by Dr. H. Schellen. Translated from the second enlarged and revised German Edition by Jane and Caroline Lassell. Edited, with Notes, by William Huggins, LL.D., D.C.L., F.R.S. 8vo. London, 1872.

Travels of Ibn Batūta. Translated from the Abridged Arabic Manuscript Copies preserved in the Public Library of Cambridge. With Notes, Illustrative of the History, Geography, Botany, Antiquities, &c., occurring throughout the Work. By the Rev. Samuel Lee, B.D. 4to. London, 1829.

System of Logic Ratiocinative and Inductive, being a connected view of the Principles of Evidence and the Methods of Scientific Investigation. By John Stuart Mill. 2 vols. 8vo. London, 1872.

Straits of Malacca, Indo-China, and China; or Ten Years' Travels, Adventures, and Residence Abroad. By J. Thomson, F.R.G.S. 8vo. London, 1875.

Origin of Civilisation, and the Primitive Condition of Man—Mental and Social Condition of Savages. By Sir John Lubbock, Bart., M.P., F.R.S. 8vo London, 1875.

Travels in Palestine, through the Countries of Bashan and Gilead, East of the River Jordan; including a Visit to the Cities of Geraza and Gamala, in the Decapolis. By J. S. Buckingham. 4to. London, 1821.

Journal of the Royal Geographical Society for 1873 and 1874.

The Statesman's Year-Book for 1875.

The Zoological Record for 1872. Edited by Alfred Brown, M.A., F.R.S.

Philosophical Transactions of the Royal Society of London. Part 2nd of Vol. 163; Parts 1st and 2nd of Vol. 164.

Report of the British Association for the Advancement of Science, held at Bradford, for 1873.

Encyclopædia Britannica. 4to. Vol. I. The Ninth Edition, 1875.

The History of Japan, from the Earliest Period to the Present Time. Vol I. to the Year 1864; Vol. II., 1865 to 1871, completing the Work. By Francis Ottiwell Adams, F.R.G.S. 2 vols. 8vo. London, 1875.

Chemical and Geological Essays. By Thomas Sterry Hunt, LL.D. 1 vol. 8vo. London, 1875.

Fragmentary Papers on Science and other Subjects. By the late Sir Henry Holland, Bart. Edited by his Son, Rev. Francis Holland. 1 vol. 8vo. London, 1875.

Water-Analysis: A Practical Treatise on the Examination of Potable Water. By J. Alfred Wanklyn and Ernest Theophron Chapman. Third Edition, entirely re-written by J. Alfred Wanklyn, M.R.C.S. 12mo. London, 1874.

Book added to Architectural Library—

School Architecture, being Practical Remarks on the Planning, Designing, Building, and Furnishing of School Houses. By Edward Robert Robson. 8vo. London, 1874.

LIST OF WEEKLY, MONTHLY, AND QUARTERLY PERIODICALS RECEIVED IN THE PHILOSOPHICAL SOCIETY'S LIBRARY.

Weekly.

Athenæum.
Architect.
Academy.
Annales Industrielles.
Builder.
Building News.
British Architect.
Chemical News.
Comptes Rendus.
Engineer.
Engineering.
Iron.
Journal of the Society of Arts.
Les Mondes.
Nature.
Notes and Queries.
Polytechnisches Journal.
Pharmaceutical Journal.

Monthly.

Annalen der Chemie und Pharmacie.
Annales de Chimie et de Physique.
Annalen der Physik und Chemie.
Annales des Ponts et Chaussees.
American Journal of Science and Art.
Annals and Magazine of Natural History.
Abstracts of the Proceedings of the Geological Society of London.
Monthly Microscopical Journal.
Geological Magazine.
Geographical Magazine.
Monatsbericht der Königlich Preussischen Akademie der Wissenschaften zu Berlin.
Journal de Pharmacie et de Chimie.
Journal fur Praktische Chemie.
Journal of the Chemical Society.
Journal of Botany.
London, Edinburgh, and Dublin Philosophical Magazine.
Monthly Notices of the Royal Astronomical Society.

Quarterly.

Bulletin de la Société Chimique de Paris.
Annales des Mines.
Journal of the Iron and Steel Institute.
Journal of the Statistical Society.
Journal of the Anthropological Society.
Quarterly Journal of Science.
Quarterly Journal of Microscopical Science.
Quarterly Journal of the Geological Society.
The Ibis, Quarterly Journal of Ornithology.

LIST OF MEMBERS.

HONORARY MEMBERS.

Foreign.

Elected in 1860—M. Chevreul, Paris.
— 1860—M. Dumas, Paris.
— 1860—Professor H. Helmholtz, Heidelberg.
— 1860—Professor Albert Kölliker, Wurtzburg.
— 1860—M. Le Verrier, Paris.
— 1860—Professor W. Weber, Leipzig.
— 1874—Robert Lewis John Ellery, Esq., F.R.A.S., Victoria.

American.

Elected in 1860—Prof. James D. Dana, Yale College, Connecticut.
— 1860—Prof. Joseph Henry, Secretary to Smithsonian Institution, Washington.
— 1860—Professor Loomis, New York.

British.

Elected in 1849—John J. Griffin, Esq., London.
— 1850—Prof. Balfour, M.D., F.R.S., Edinburgh.
— 1860—Dr. J. P. Joule, Manchester.
— 1860—Gen. Sabine, R.A., London.
— 1874—Lewis D. B. Gordon, Esq., F.R.S.E., F.G.S., London.
— 1874—Prof. A. C. Ramsay, LL.D., F.R.S., London.
— 1874—Dr. J. D. Hooker, F.R.S., London.
— 1874—Dr. R. A. Smith, F.R.S., F.C.S., Manchester.
— 1875—Wm. Froude, C.E., F.R.S., Chelston Cross, Torquay.

CORRESPONDING MEMBERS.

Elected in 1874—James Bryce, M.A., LL.D., F.G.S., F.R.S.E., 25 London Road, Edinburgh.
— 1874—Rev. H. W. Crosskey, F.G.S., Edgbaston, Birmingham.
— 1874—Robert Gray, F.R.S.E., Bank of Scotland, Edinburgh.
— 1874—Prof. A. S. Herschel, B.A., F.R.A.S., 16 Saville Row, Newcastle-on-Tyne.
— 1874—Thomas E. Thorpe, Ph.D., F.R.S.E., Professor of Chemistry, Leeds.

ORDINARY MEMBERS,

With Year of Entry.

Buchanan, Andrew, M.D., Prof. of Institutes of Medicine in the University of Glasgow, 186 Bath street. 1833.
Hart, Robert, Cessnock Park, Govan road. 1820.
Stewart, John, Annat Lodge, Helensburgh. 1822.

(The above are Original Members.)

Adams, James, 9 Royal crescent. 1874.
5 Adamson, John, Clayton Cottage, Westercraigs, Dennistoun. 1872.
Addie, John, 144 St. Vincent street. 1861.
Alexander, James, Jun., 153 St. Vincent street. 1870.
Alexander, Thos., 8 Sardinia terrace. 1869.
Allan, Thomas, Springbank. 1850.
10 Anderson, Alexander, 114 Trongate. 1869.
Anderson, Geo., M.P., Western Club. 1856.
Anderson, John, 48 Dundas street. 1871.
Anderson, John, Bank of Scotland, Glasgow. 1873.
Anderson, T. M'Call, M.D., Professor of Clinical Medicine in the University of Glasgow, 14 Woodside cres. 1873.
15 Armstrong, James, 16 Albert drive, Crosshill. 1859.
Armstrong, Wm. J., 3 Royal Exchange court. 1871.
Arnot, James Craig, 139 West Campbell street. 1869.
Arrol, Archibald, 16 Dixon street. 1869.
Arrol, Walter, 16 Dixon street. 1869.
20 Arrol, William A., 16 Dixon street. 1869.
Arthur, Allan, 7 Alfred terrace, Gt. Western road. 1869.
Arthur, William Rae, 1 Crown gardens, Dowanhill. 1850.
Aspin, James, 1 India street, West. 1870.
Auchterlonie, Thomas B., Bellfield, Kirkintilloch. 1869.

25 Bain, Jas., F.R.S.E., 3 Park terrace. 1866.
Bain, Robert, 22 Dundas street. 1869.
Baird, Alex. Smith, 12 Sardinia terrace, Hillhead. 1870.
Baird, Wm., 7 Hampden terrace, Queen's Park. 1875.
Baldie, Robert, I.A., 83 Bath street. 1870.
30 Balloch, Robert, 88 Union street. 1848.
Bankier, W. D., 31 St. Vincent place. 1874.
Bannatyne, Mark, 145 W. George st. 1872.
Barclay, Jas., 224 West George st. 1872.
Barr, T. M., C.E., 16 Dalhousie st. 1869.
35 Baxter, John W., Linnside, Dunoon. 1862.
Baxter, Wm., 14 Gibson st., Hillhead. 1873.
Beckett, John, 16 St. Vincent place. 1872.
Bell, Dugald, 27 Lansdowne crescent. 1871.
Bell, George, I.A., 37 West Nile st. 1870.
40 Bell, James, 41 Mitchell street. 1848.
Bell, Robt., M.D., F.F.P.S.G. and Ed., 29 Lynedoch street. 1869.
Bird, Gregory, 8 Berkeley terrace. 1866.
Bischof, Gustav, Professor of Technical Chemistry, Andersonian University. 1871.

Black, J. Albert, 16 Park terrace. 1869.
45 Black, John, 16 Park terrace. 1869.
Black, D. Campbell, M.D., M.R.C.S.E., 25 Sandyford place. 1872.
Blackie, Robert, 17 Stanhope street. 1847.
Blackie, W. G., Ph.D., F.R.G.S., 17 Stanhope street. 1841.
Blair, G. M'Lellan, 3 Woodlands ter. 1869.
50 Blair, J. M'Lellan, 8 Cecil pl., Paisley rd. 1869.
Boucher, J., I.A., 217 W. George st. 1870.
Bowie, Andrew, 5 India street. 1867.
Bowie, Campbell T., 26 Bothwell st. 1870.
Boyd, John, Shettleston Iron Works, near Glasgow. 1873.
55 Boyd, Wm., Blythswood Foundry, 61 North street. 1852.
Brodie, John Ewan, M.D., C.M., 99 Douglas street. 1873.
Bromhead, Horatio K., A.R.I.B.A., 194 St. Vincent street. 1870.
Broom, William, 182 Hope street. 1852.
Brown, Alfred, 79 West Regent st. 1863.
60 Brown, John, Messrs. Thomson & Co., 62 Buchanan street. 1874.
Brown, Nicol, 136 West George st. 1869.
Brown, Richard, Eglinton Chemical Co., 31 St. Vincent street. 1855.
Brownlee, Jas., 30 Burnbank gardens. 1860.
Brownlee, Thomas, Springbank Villa, Lenzie. 1872.
65 Brownlie, John, Whitehill street. 1874.
Bruce, John Inglis, 62 Robertson st. 1869.
Bruce, John L., 103 West Regent st. 1873.
Bryce, David, 129 Buchanan street. 1872.
Bryden, Robert A., 15 Dalhousie st. 1870.
70 Buchanan, George, M.D., Professor of Clinical Surgery in the University of Glasgow, 193 Bath street. 1875.
Buchanan, Geo. S., 95 Candleriggs. 1845.
Buchanan, R. M., 11 Park Grove ter. 1872.
Buchanan, Wm. L., 48 Gordon st. 1873.
Burnet, John, 167 St. Vincent street. 1850.
75 Burns, J. Cleland, Ochtertyre, Crieff. 1874.
Burns, J., M.D., 15 Fitzroy place, Sauchiehall street 1864.
Byers, A. Stewart, 6 S. Wellington st. 1870.

Cameron, Chas., M.D., LL.D., M.P., 104 Union street. 1870.
Cameron, R., 61 Parliamentary rd. 1873.
80 Cameron, H. C., M.D., 294 Bath cres. 1873.
Campbell, J. A., LL.D., 29 Ingram st. 1848.
Campbell, John D., 5 Derby ter., Sandyford. 1858.
Cannan, John, 248 Buchanan street. 1870.
Carlile, Thomas, 28 West Nile street. 1851.
85 Carlton, Charles, 141 St. Vincent st. 1870.
Carmichael, Neil, M.D., C.M., 22 Cumberland street. 1873.
Carrick, James, 43 W. Regent street. 1862.
Carrick, John, City Architect, 4 S. Albion place. 1846.
Cassels, Robt., 166 St. Vincent st. 1858.
90 Cassells, J. P., M.D., 2 Newton ter. 1874.
Chalmers, John, 251 Renfrew street. 1871.
Chapman, Thomas, 56 Buchanan st. 1849.
Charteris, Matthew, M.D., 8 Blythswood square. 1869.

Christie, A., 28 Buchan st., Gorbals. 1855.
95 Christie, John, Turkey-red Works, Alexandria, Dumbartonshire. 1863.
Church, James, 88 Renfield street. 1857.
Church, Wm., jun., 67 St. Vincent st. 1855.
Clapperton, John, 5 Sandyford pl. 1874.
Clark, John, Ph.D., 138 Bath street. 1870.
100 Clark, John, 9 Wilton crescent. 1872.
Clarke, Wm., I.A., 37 W. Nile st. 1870.
Clavering, Thos., 21 St. Vincent pl. 1856.
Clinkskill, Jas., 176 W. Regent st. 1869.
Clouston, Peter, 17 Exchange sq. 1861.
105 Coats, Joseph, M.D., 33 Elmbank street. 1873.
Cochrane, Michael, M.A., 28 Gardner street. 1871.
Coghill, Wm. C., 263 Argyle street. 1873.
Coleman, J. J., F.C.S., 69 St. George's place 1863.
Collier, William F., LL.D., 12 Belmont crescent, Gt. Western road. 1870.
110 Collins, Wm., 3 Park terrace, East. 1869.
Colquhoun, Hugh, M.D., Anchorage, Bothwell. 1842.
Connal, Michael, Virginia buildings. 1848.
Connell, James, 182 Crookston st. 1870.
Connell, Wm., 38 St. Enoch square. 1870.
115 Connel, Robt., M.D., 2 Royal crescent, West. 1872.
Copeland, Jas., 2 Portman place, Smith st., Hillhead. 1869.
Corbet, Robert, 70 Ferdneuk st. 1870.
Coubrough, A. Sykes, Blanefield, Strathblane. 1863.
Couper, James, Craigforth House, Stirling. 1862.
120 Couper, Wm., 9 Huntly gardens, Hillhead. 1873.
Cowan, J. B., M.D., Professor of Materia Medica in the University of Glasgow, 159 Bath street. 1865.
Cowan, John, 4 Derby street. 1870.
Craig, John, 24 Hamilton Park ter. 1873.
Crawford, David, Jun., Tureen street Dye-works, Calton. 1873.
125 Crawford, Wm. C., M.A., Eagle Foundry. 1863.
Crawford, W. B., 104 W. Regent st. 1872.
Cree, Thomas S., 17 Exchange sq. 1869.
Cross, David, 51 Argyle street. 1856.
Culbard, A. D. Fordyce, 70 Miller st. 1875.
130 Cumming, J. Simpson, M.D., 310 St. Vincent street. 1874.
Cunliff, Richard S., 28 Renfield st. 1833.
Currie, R. L., 138 West Regent st. 1867.
Cuthbertson, John N., 29 Bath st. 1856.

Darling, Geo. E., 247 W. George st. 1870.
135 Davidson, John, Gas Manager, 13 Winton terrace, Crosshill. 1874.
Davidson, T., Jun., 83 Garngad hill. 1872.
Day, St. John Vincent, C.E., F.R.S.E., 166 Buchanan street, *Librarian.* 1866.
Deas, James, C.E., 7 Crown gardens, Dowanhill. 1869.
Dick, A. Buchanan, 76 Milton st. 1871.
140 Dickson, James, 34 Kent street. 1871.
Dickson, G. Irving, 37 W. George st. 1871.

Dixon, Edward M., B.Sc., 11 Hopetoun place. 1860.
Dixon, Joseph Anthony, 156 W. George street. 1870.
Dixon, Peter W., 19 Elmbank cres. 1871.
145 Dixon, A. Dow, 19 Elmbank cres. 1873.
Doddrell, Geo. John, 45 Virginia st. 1864.
Donald, John, 42 Cadogan street. 1867.
Donald, John, St. Rollox Schools. 1872.
Donaldson, Alex., 103 St. Vincent st. 1865.
150 Donaldson, James, M.D., Deputy Inspector General of Hospitals, 6 Granby terrace, Hillhead. 1874.
Douglas, Campbell, I.A., 266 St. Vincent street. 1870.
Douglas, Wm., 22 W. Nile street. 1874.
Douie, Robert, 145 Ingram street. 1869.
Downie, James, 69 Ingram street. 1872.
155 Downie, Robert, Jun., Carntyne Dye-works, Parkhead. 1872.
Drew, Alex., 31 Hamilton drive. 1869.
Dron, William, Cranstonhill. 1873.
Dryburgh, James N., 93 N. Frederick street. 1872.
Duncan, William, Coltness Iron Co., 124 St. Vincent street. 1865.
160 Duncan, Eben., M.D., C.M., F.F.P.S.G., 4 Royal crescent, Crosshill. 1873.
Duncan, Robert, Engineer, Partick Foundry. 1875.
Dunlop, Nathaniel, 8 Albany place. 1870.
Dunn, Jas., 34 Burnbank gardens. 1858.

Ellison, W. T., Cleansing Department, Parliamentary road. 1871.
165 Evans, Mortimer, C.E., F.G.S., 97 West Regent street. 1873.

Fairlie, Colin B., C.E., 67 Renfield st. 1874.
Fairlie, Jas. M., 17 St. George's rd. 1874.
Farquhar, John, Tower Bank, Lenzie. 1872.
Fergus, Andw., M.D., M.R.C.S. Eng., 41 Elmbank st., *Vice-President.* 1868.
170 Ferguson, John, M.A., Professor of Chemistry in the University of Glasgow. 1869.
Ferguson, Peter, 2 Rochester pl., Sauchiehall street. 1866.
Fergusson, Alex. A., 38 M'Alpine street. 1847.
Fergusson, Alex., 31 Elmbank cres. 1870.
Findlay, Joseph, 25 Lynedoch st. 1873.
175 Finlay, John, 18 Renfield street. 1850.
Finlayson, Jas., M.D., 351 Bath st. 1873.
Fisher, Donald, 183 St. Vincent st. 1869.
Fleming, J. G., M.D., 155 Bath st. 1841.
Forbes, Peter, Larbert Cottage, Larbert. 1868.
180 Forbes, George, B.A., F.R.S.E., Professor of Natural Philosophy in the Andersonian University. 1872.
Forrester, James M., 107 St. Vincent street. 1869.
Foulis, William, 42 Virginia street. 1870.
Frame, Thomas, Royal Bank place. 1863.
Frazer, Daniel, 113 Buchanan street. 1853.
185 Frew, Robt., M.E., 51 W. Regent st. 1874.
Fulton, David, Engraving Works, Duke street. 1872.

Gairdner, W. T., M.D., Professor of Practice of Physic in the University of Glasgow, 225 St. Vincent street. 1863.
Galbraith, Andrew, 123 Hope street. 1857.
Galbraith, James, M.A., LL.B., 68 Bath street. 1875.
190 Galbraith, Wm., 3 Blythswood sq. 1868.
Gale, Jas. M., C.E., Water Office, 23 Miller street. 1856.
Gardner, Daniel, 36 Jamaica street. 1869.
Gardner, O. T. B., 3 W. Prince's st. 1869.
Gardner, George, 20 Buchanan st. 1873.
195 Garroway, Robert, 58 Buchanan st. 1859.
Geddes, Wm., Battlefield, Langside. 1846.
Gentles, William, 338 Sauchiehall st. 1870.
Gillies, Wm., Battlefield, Langside. 1869.
Gillies, W. D., 10 Princes square. 1872.
200 Gilmour, J. B., 50 N. Hanover st. 1865.
Goldie, Alex., 78 Rutherglen loan. 1870.
Gorman, William, 13 Renfrew st. 1860.
Gossman, Adam, 23 Carlton place. 1870.
Gourlay, John, C.A., 128 St. Vincent street. 1874.
205 Gourlay, Robert, 10 Howard street. 1869.
Gourlay, Robert, Bank of Scotland. 1873.
Gow, Alexander, 117 Ladbroke Grove rd., Nottinghill, London, W. 1869.
Gow, Robert, Cairndowan, Dowanhill gardens. 1860.
Grant, Robert, M.A., LL.D., F.R.S., Professor of Astronomy in the University of Glasgow; Observatory. 1860.
210 Gray, Charles, 193 Renfrew street. 1870.
Gray, James, M.D., 15 Newton ter. 1868.
Greenlees, Alex., M.D., 405 St. Vincent street. 1864.
Greenlees, William, M.D., Summerhall Brewery, Edinburgh. 1870.
Gregory, T. Currie, C.E., F.G.S., 150 St. Vincent street. 1858.
215 Grieve, John, M.D., 21 Lynedoch st. 1856.
Grieve, Robt., L.R.C.S., Ed., 52 Holmhead street. 1872.
Guthrie, David, C.E., 23 Miller st. 1860.
Guthrie, William, 23 Miller street. 1868.

Hallows, Frederic J., 133 West George street. 1872.
220 Hamilton, Andrew, Thornliebank. 1872.
Hamilton, Geo., 149 St. Vincent st. 1871.
Hamilton, J. Struthers, Adelphi Cotton Works. 1869.
Hamilton, Patrick, 149 St. Vincent street. 1854.
Hannah, Robert S., 80 Buchanan st. 1873.
225 Hannay, Anthony, 23 Exchange sq. 1856.
Hannay, Thomas, 21 St. Vincent pl. 1864.
Harvey, Alexander, Sen., 4 S. Wellington place. 1870.
Harvey, George, 9 Park quadrant. 1845.
Harvey, J. E., 2 Bath street. 1851.
230 Hay, John, 110 Bothwell street. 1870.
Heinzerling, Chr., Ph.D., Andersonian University. 1874.
Henderson, Thos., 47 Union street. 1855.

Henderson, William, [illegible] New wynd. 18[illegible]
Henderson, Wm., 17 Buchanan st. 18[illegible]
255 Henderson, Wm., [illegible] Renfield st. 187[illegible]
Henry, J. W., [illegible] street. 187[illegible]
Hetherington, Henry, [illegible] St. Vincent street. 1870.
Herron, Arthur, 22 Wilson street. 1869.
[illegible], [illegible]. 1870.
260 Higginbotham, James [illegible], [illegible] St. Vincent street. 187[illegible].
Hinshelwood, John, [illegible] St. James st. 1871.
Hislop, James, [illegible] House, Maryhill. 187[illegible]
Hoey, David [illegible], [illegible] St. Vincent st. 1868.
Hogg, James, [illegible] Renfield street. 1866.
265 Holms, Wm., M.P., [illegible] Park circus. 186[illegible]
Honeyman, John, [illegible], [illegible] Bath street. 1871.
Houston, Campbell, Renfrew Villa, Pollokshields. 1872.
Howat, James, [illegible] Buchanan st. 1871.
Howat, William, [illegible] Buchanan st. 1871.
270 Hunt, [illegible], [illegible] St. Vincent st. 1864.
Hunter, Andw., 31 Woodside place. 1871.
Hunter, Jas., Newmains House, Motherwell. 1864.
Hunter, James, [illegible] St. Vincent st. 1874.
Hutchison, John, [illegible] St. [illegible] ter. 1868.
275 Hutton, W. R., [illegible] Renfield street. 1866.

Inglis, Anthony, 64 Warroch street. 1854.
Inglis, John, 64 Warroch street. 1860.
Irvine, A. K., M.D., [illegible] Newton ter. 1856.

Jack, John E., 4 Florentine terrace, Hillhead. 1871.
280 Jackson, John H., 2[illegible] Bath street. 1871.
Jackson, Thomas, [illegible] House, Cambridge. 1857.
Jamieson, Gustav, Prospect Villa, Montgomery ter., Mount Florida. 1872.
Jamieson, John L. K., 12 Centre st. 1869.
Jeffrey, John, 1[illegible] St. Vincent st. 1869.
285 Johnson, Rev. J. S., D.D., Manse, Cambusnang. 1870.
Johnstone, James, Cambridge st., Port-Dundas. 1869.
Johnston, John, 52 W. Howard st. 1867.
Jones, William, 2[illegible] Bath crescent. 1872.

Keddie, Wm., F.R.S.E., 5 India street, *Secretary.* 1843.
290 Kennedy, Thomas, Jun., 3 N. Exchange court. 1869.
Kennedy, Walter Stewart, Allanbank, Crosshill. 1873.
Ker, Wm., 1 Windsor ter., West. 1874.
Kerr, James Henry, 20 Dunlop st. 1872.
King, James, 6 Windsor ter., St. George's road. 1855.
295 King, James, Hurlet and Campsie Alum Company, 204 W. George st. 1855.
King, John, 18 Renfield street. 1872.
Kirk, Alexander C., Govan park, Govan road. 1869.
Kirkpatrick, Andrew J., 10 Woodside place. 1869.

Kirkwood, Anderson, LL.D., [illegible] Windsor terrace, West. 1869.
300 Knox, John, [illegible] Argyle street. 1866.
Knox, [illegible] L., Montgomerie Drive, Kelvinside, Great Western road. 1869.
Knox, John, 1[illegible] W. George street. 1871.

Laing, Alex., LL.D., Professor of Mathematics in the Andersonian University. 1846.
Laird, Geo., [illegible] st., Bridgeton. 1871.
305 Laird, Hugh, Jun., Clydesdale Bank, Argyle street. 18[illegible]
Lamb, James, 7[illegible] Wilson street. 1871
Lamb, Thos., [illegible] Parliamentary rd. 1871.
Lang, Wm., Jun., [illegible] W. George st. 1865.
Langlands, Andrew, C.E., [illegible] W. George street. 18[illegible]
310 Leggat, Robert, [illegible] Sauchiehall st. 1868.
Lesser, Louis, [illegible] West George st. 1869.
Lindsay, Wm. G., [illegible] W. Regent st. 18[illegible]
Lindsay, [illegible] M., M.A., [illegible] W. Regent street. 187[illegible]
Lindsay, Rev. Thomas M., D.D., M.A., F.R.S.E., F.A.S., Professor in the Free Church College. 187[illegible]
315 [illegible], John, [illegible] St. George's road. 1871.
Long, John [illegible], 22 [illegible]. 186[illegible]
Lowson, J. Alexander, M.D., L.R.C.S.E., [illegible] Sauchiehall st. 187[illegible]
Lumsden, Sir James, [illegible] Queen st. 18[illegible]

M'Adam, William, [illegible] [illegible] st. 18[illegible]
320 M'Adam, William, Jun., [illegible] St. Vincent crescent. 18[illegible]
M'Alley, Robert, Chemical Works, Falkirk. 187[illegible]
M'Andrew, John, [illegible] Park st., East. 18[illegible]
M'Arthur, Alex., [illegible] [illegible] st. 186[illegible]
M'Arthur, Jn., 36 [illegible] street. 187[illegible]
325 Macarthur, J. G., [illegible] St. Vincent st. 187[illegible]
MacBean, Hugh, 2[illegible] [illegible] place. 18[illegible]
M'Call, J., V.S., Professor of Veterinary Medicine and Surgery, Veterinary Col., 83 Buccleuch st. 186[illegible]
M'Callum, Geo., [illegible], Cambuslang. 185[illegible]
M'Call, Alex., 247 Bath street. 187[illegible]
330 M'Cartale, John, M.D., 27 Elmbank place. 187[illegible]
M'Cowan, Robert, C.A., 87 St. Vincent street. 1869.
M'Creath, James, M.E., 138 W. George street. 1874.
M'Culloch, Richd., 4 North court, Royal Exchange. 1872.
M'Culloch, William, 134 Bath st. 1872.
335 Macdonald, Archd. G., 8 Park circus. 1869.
M'Donald, Jno., Comely Park House. 187[illegible]
Macdonald, Thomas, 203 Hope st. 1869.
M'Ewan, Malcolm, 55 E. Howard st. 1874.
M'Ewen, Wm., Jun., 11 Park ter. 1869.
340 Macfarlane, Walter, Saracen Foundry, Possil park. 1870.
M'Farlane, Walter, Printworks, Thornliebank. 1869.
M'Farlane, Robt., 28 Napiershall st. 1872.
M'Gavin, John, 19 Elmbank place. 1869.

MacGill, J. S., 2 Clifton street. 1869.
325 M'Gregor, Duncan, F.R.G.S., 45 Clyde place. 1867.
M'Gregor, Jas. W., 4 Great Western ter., Hillhead. 1869.
M'Gregor, David, Manager, Allander Printworks, Milngavie. 1872.
M'Gregor, James, 1 East India Avenue, London, E.C. 1872.
M'Grigor, Alexander B., 136 St. Vincent street. 1857.
330 Machattie, Alex T., Ph.D., F.C.S., 88 Hope street. 1875.
M'Ilwraith, James, 6 Berkeley ter. 1872.
M'Intosh, James, 129 Stockwell st. 1855.
M'Intyre, Peter, 20 Ingram street. 1873.
Mackay, John, Jun., 354 Sauchiehall street. 1869.
335 Mackenzie, W. D., 43 Howard st. 1875.
M'Kendrick, John, 54 Port street, Cranstonhill. 1869.
Mackinlay, David, 6 Gt. Western ter., Hillhead. 1855.
M'Kinnon, Alex., 1 Holland street. 1875.
M'Laren, Robert, Canal st., Port-Eglinton. 1848.
340 M'Laren, Wm. Ed., 30 Renfield st. 1873.
Maclean, A. H., 124 Queen street. 1870.
Maclean, Thomas, 124 Queen street. 1870.
Maclean, William, Jun., 98 West George street. 1869.
Maclehose, James, 18 Victoria cres., Dowanhill. 1867.
345 Macleish, J. M., 10 Hamilton drive, Hillhead. 1874.
Maclellan, A. H., 6 Lansdowne cres. 1870.
M'Lellan, Lewis, 26 India street. 1869.
M'Lellan, Walter, 129 Trongate. 1856.
Macleod, Kenneth M., 1 Montrose st. 1870.
350 Macnee, Daniel, R.S.A., 178 Bath street. 1855.
M'Nicol, Peter, M.A., 186 North st. 1873.
M'Onie, Andrew, Scotland street, Tradeston. 1860.
M'Pherson, Jas., M.D., 115 Bath st. 1869.
M'Pherson, George L., 17 Albert drive, Crosshill. 1872.
355 Mactear, James, F.C.S., St. Rollox Chemical Works. 1867.
M'Vail, D. C., 226 Gt. Western rd. 1873.
Main, James, A.R., 9 Renfield st. 1870.
Malloch, Charles, 28 Miller street. 1870.
Manford, Stewart, 24 Oswald street. 1874.
360 Mann, John, C.A., 83 West Regent street, *Treasurer*. 1856.
Marshall, James, 8 Somerset place. 1869.
Marshall, James, Sunnyside, Partickhill. 1875.
Martin, John M., 142 St. Vincent st. 1865.
Martin, Thomas, 166 Sauchiehall st. 1862.
365 Martin, Thos., 19 Rupert st., Gt. Western road. 1871.
Mason, Stephen, 47 Queen street. 1870.
Masterton, Robert Knox, 88 Elmbank terrace. 1871.
Mathieson, John A., 211 Hope st. 1851.
Mathieson, Thomas A., 13 East Campbell street. 1869.
370 Mayer, John, F.C.S., 2 Linden ter., Pollokshields. 1860.
Mayer, E. L., 195 St. George's rd. 1872.
Mein, Alex., 12 Buckingham ter. 1857.
Meldrum, Edward, of Dechmont, Uphall. 1852.
Melvin, Wm., 89 South Portland st. 1870.
375 Menzies, Thomas, Hutchesons' Hospital School, Crown street. 1859.
Middleton, Robert T., 57 W. Nile st. 1860.
Millar, David, 6 Royal terrace. 1873.
Millar, Jas., 134 Parliamentary rd. 1870.
Millar, William, 3 Woodside ter. 1873.
380 Miller, Alexander, Jun. (Messrs. Inglis & Wakefield), 74 Gordon st. 1873.
Miller, Daniel, C.E., 203 St. Vincent street. 1851.
Miller, Hugh, M.D., F.F.P.S., 298 Bath street. 1872.
Miller, James, Port-Dundas Pottery. 1863.
Miller, James, 21 Woodside place. 1869.
385 Miller, John S., 54 Gordon street. 1845.
Miller, John (Messrs. James Black & Co.), 23 Royal Exchange square. 1874.
Miller, Thomas P., Cambuslang Dye Works. 1864.
Miller, W. M., 5 Shaftesbury ter., West Regent street. 1867.
Miller, William, 147 St. Vincent st. 1869.
390 Miller, William, 7 Victoria ter., Dowanhill. 1873.
Mirrlees, James B., 45 Scotland st., Tradeston. 1869.
Mitchell, Alexander, Jun., 10 Wilton crescent. 1870.
Mitchell, Angus, 42 Miller street. 1872.
Mitchell, Robert, 54 Carnarvon st. 1870.
395 Moffatt, Alexander, 47 Union street. 1874.
Moir, P. M., 51 Crawford street, Port-Eglinton. 1868.
Moore, Alexander, C.A., 166 St. Vincent street. 1869.
Moore, Wm., M.E., 49 W. George st. 1860.
Morgan, John, Springfield House, Bishopbriggs. 1844.
400 Morrice, Alex., 27 Abbotsford pl. 1873.
Morrison, George, 19 Royal terrace. 1872.
Morrison, George R., 10 Belgrave ter., Hillhead. 1875.
Morrison, James, 98 Sauchiehall st. 1869.
Morton, Alex., 96 Buchanan street. 1869.
405 Morton, James, M.D., Professor of Materia Medica in the Andersonian University, 199 Bath st. 1868.
Mossman, John, 21 Elmbank cres. 1870.
Muir, Matthew, 17 Carlton place. 1866.
Muir, Matthew A., 20 Park terrace. 1861.
Muir, Thomas, 17 Carlton place. 1856.
410 Muir, Thomas, M.A., F.R.S.E., High School. 1874.
Muirhead, Andrew Erskine, Cart Forge, Crossmyloof. 1873.
Muirhead, Henry, M.D., Bushy Hill, Cambuslang. 1869.
Muirhead, Thomas, 5 Allanton ter., Crosshill. 1872.
Munro, Daniel, 7 Park quadrant. 1867.
415 Munsie, George, 345 Bath street. 1871.

Murdoch, James B., Hamilton place, Langside. 1855.
Murdoch, Jas., Glennenk, Port-Glasgow. 1857.
Murray, John Bruce, 97 Mitchell st. 1872.
Murray, George, 97 Mitchell street. 1872.
420 Murray, Geo. R., Manufacturing Chemist, Maryhill. 1874.

Nairn, Archibald, 24 Cochran st. 1870.
Napier, James, F.C.S., Cuprum House, Partick. 1849.
Napier, Jas., Jun., 21 Roselea drive. 1870.
Napier, James R., F.R.S., 22 Blythswood square. 1850.
425 Napier, John, Saughfield House, Hillhead. 1849.
Neil, John, Whitehill House, Dennistoun. 1872.
Neilson, Walter, 172 W. George st. 1856.
Neilson, Walter M., Hydepark Works, Springburn. 1870.
Neilson, William, 48 Renfield street. 1871.
430 Nelson, D. M., 48 Gordon street. 1875.
Newhaus, Albert, 1 Prince's terrace, Dowanhill. 1874.
Nicol, David, 18 Nelson terrace, Hillhead. 1872.
Nicol, James, City Chambers. 1872.
Nicolson, Thos., 188 St. Vincent st. 1858.

435 Ogilvie, Thomas Robertson, F.C.S., 19 Brisbane street, Greenock. 1875.
Osborne, Alex., 5 Oakley terrace, Dennistoun. 1870.

Paris, William, Glasgow Iron Works, St. Rollox. 1869.
Paris, William, Jun, Glasgow Iron Works. 1872.
Parnie, James, 26 Lynedoch street. 1874.
440 Paterson, Adam, LL.D., 45 West George street. 1843.
Patterson, T. L., F.C.S., at John Walker & Co.'s, Greenock. 1873.
Peden, William N., 8 Hilton terrace, Crosshill. 1872.
Pennycook, C. H., 100 Montrose st. 1869.
Peters, John, 29 S. Shamrock st. 1874.
445 Pickering, John, 5 Royal crescent. 1875.
Pickering, Robert, 10 Albany place. 1875.
Pollock, Morris, 12 Park terrace. 1875.
Poynter, John E., 8 Princes sq., Buchanan street. 1866.
Pringle, Quintin, B.Sc., B.A., LL.B., 66 Hamilton pl., Gt. Western rd. 1872.
450 Provan, James, 17 Gordon street. 1868.

Ramsay, John, of Kildalton, M.P., 49 Dunlop street. 1856.
Ramsay, William, C.E., 49 West George street. 1841.
Randolph, Charles, 14 Park terrace. 1836.
Rankine, Capt. John, 10 W. Garden street, Burnbank. 1869.
455 Raphael, Robert, 146 W. George st. 1868.
Readman, Robert, Westfield ter., Partick. 1848.
Reid, Douglas, Easterton, Helensburgh. 1874.
Reid, James, 10 Woodside terrace. 1870.
Reid, James, Dunmullin House, Strathblane. 1855.
460 Reid, J. G., 87 St. Vincent cres. 1874.
Reid, Thos., M.D., 11 Elmbank st. 1869.
Renison, William, 124 Hope street. 1856.
Renshaw, C. Buie, Glenpatrick, by Paisley. 1870.
Richardson, Geo., 115 St. Vincent st. 1869.
465 Ritchie, Wm., Jun., Kincaidfield House, Milton of Campsie. 1870.
Roberton, James, LL.D., Professor of Conveyancing in the University of Glasgow, 13 Newton place. 1871.
Robertson, Andw. Carrick, 116 St. Vincent street. 1874.
Robertson, Archibald, 25 Queen st. 1863.
Robertson, David, F.G.S., 108 Woodlands road. 1859.
470 Robertson, David, 41 West Nile st. 1872.
Robertson, James, 1 Clifford street, Paisley road. 1865.
Robertson, John, Newhall Factory, Greenhead. 1858
Robertson, John, 83 Cumberland st., west. 1860.
Robertson, R. Blair, 1 Hillhead pl., Hillhead. 1872.
475 Robertson, Thos., 122 Wellington st. 1874.
Robertson, Wm., C.E., 123 St. Vincent street. 1869.
Roger, Wm., C.E., 131 Hope st. 1875.
Rottenburg, Paul, 146 W. George st. 1872.
Rowan, David, 22 Woodside place. 1863.
480 Rowan, W. H., Clydeford, Rutherglen. 1874.
Russell, James B., B.A., M.D., 1 Montrose street. 1862.
Russell, Thomas, 14 India street. 1870.

Salmon, James, I.A., 197 St. Vincent street. 1870.
Salmon, W. Forrest, I.A., 197 St. Vincent street. 1870.
485 Sandeman, D., Woodlands, Lenzie. 1870.
Schuman, Sigismund, 7 Royal Bank place. 1866.
Scott, Alex., 19 St. Vincent crescent. 1871.
Scott, James, 6 Wilton crescent. 1869.
Scott, E. J., 24 Sardinia terrace. 1872.
490 Scott, Thomas, 1 North Ure place. 1873.
Seligmann, Hermann L., 29 St. Vincent place. 1850.
Selkirk, James L., 136 Buchanan st. 1871.
Sellars, Jas., Jun, 266 St Vincent st. 1873.
Sheppard, Wm., Govan Colliery. 1875.
495 Short, Thomas, 4 Kelvingrove st. 1874.
Sim, William, 88 Great Clyde st. 1862.
Sinclair, Neil, 42 Miller street. 1872.
Smart, Robert, M.D., 22 St. George's road, 1873.
Smellie, Thos. D., 209 St. Vincent st. 1871.
500 Smith, A. Wood, M.D., F.F.P.S.G., 5 Newton terrace. 1870.
Smith, Geo., Sun Foundry, Parliamentary road. 1870.

Smith, J. P., C.E., Haughhead cottage, Govan road. 1867.
Smith, James, Benvue, Dowanhill. 1869.
Smith, James, 21 Bath street. 1869.
505 Smith, Hugh C., 54 Gordon street. 1861.
Smith, Napier, 63 St. Vincent st. 1869.
Smith, Robert, 168 Sauchiehall st. 1860.
Smith, William, 20 Ropework lane. 1854.
Smith, W. R. W., 6 S. Hanover st. 1868.
510 Smith, Wm. A., 6 S. Hanover st. 1870.
Smith, James Graham, 18 Park Circus place, Park street, East. 1873.
Spencer, John, 2 Rosslyn terrace, Dowanhill. 1874.
Stanford, Edward C. C., F.C.S., Carruth, Bridge of Weir. 1864.
Steel, James, 25 Holmhead street 1870.
515 Steel, James, 302 St. Vincent st. 1875.
Stephen, Robert R., Adelphi Biscuit Factory. 1867.
Steven, Alex., Jun., 6 South Park terrace, Hillhead. 1867.
Steven, Hugh, 4 Buckingham ter. 1869.
Steven, John, 12 Walworth terrace. 1875.
520 Steven, William, 481 London road. 1870.
Stevenson, Jas., Jun., 23 W. Nile st. 1870.
Stevenson, Robt., 52 N. Frederick st. 1863.
Stevenson, William, 4 Berkeley ter. 1870.
Stewart, David, 128 Ingram street. 1856.
525 Stewart, David Y., 3 Provan place, North Montrose street. 1849.
Stewart, James R., 30 Oswald st. 1845.
Stewart, John, 8 Montague place, Bath street. 1869.
Stewart, John, 29 Napiershall st. 1875.
Stewart, Peter, M.D., 1 Albany pl. 1847.
530 Stewart, William, 99 St. Vincent st. 1869.
Stillie, Thomas L., 21 St. Vincent pl. 1869.
Stoddart, James Edward, Clyde Lead Works, Crookston street. 1872.
Storer, David, Colour Works, Sydney street. 1869.
Storer, James, 8 Annfield place. 1875.
535 Strathern, John, Turkey-red Dye Works, Blantyre. 1870.
Stronach, Alexander, City of Glasgow Bank. 1873.
Sutherland, Robt., 4 La Belle place. 1873.
Swan, William, Collina Cottage, Maryhill. 1870.
Swanston, John, 1 Grafton square. 1872.
540 Symington, Andrew, 119 St. Vincent st. 1873.
Tatlock, Robt. R, F.R.S.E., F.C.S., 138 Bath street. 1868.
Taylor, John, Jun., 28 Cochran st. 1855.
Taylor, Benjamin, 18 Berkeley ter. 1872.
Taylor, William G., Jun., Gartmore villa, Battlefield, Langside. 1874.
545 Teacher, Adam, 12 St. Enoch sq. 1868.
Teacher, Donald M., 36 Regent Park sq., Queen's Park. 1874.
Teacher, Wm., 12 St. Enoch square. 1858.
Tennant, Charles, St. Rollox Chemical Works. 1868.
Tennant, John, 115 St. Vincent st. 1843.
550 Thomson, Alexander, 122 Wellington street. 1870.

Thomson, Allen, M.D., LL.D., F.R.S., Professor of Anatomy in the University of Glasgow, *Vice-President.* 1849.
Thomson, David, I.A., 29 St. Vincent place. 1869.
Thomson, George, 69 Ingram street. 1859.
Thomson, George P., 2 Newton pl. 1874.
555 Thomson, Graham Hardie, 10 Donne ter., North Woodside. 1869.
Thomson, James, F.G.S., 276 Eglinton street. 1863.
Thomson, James, Allan & Mann's, 48 St. Enoch square. 1870.
Thomson, James, I.A., 61 West Regent street. 1870.
Thomson, James R., Clydebank Foundry. 1863.
560 Thomson, James, LL.D., C.E., Professor of Engineering in the University of Glasgow, Oakfield House, University avenue, Hillhead. 1874.
Thomson, John D., 4 Rosslyn ter., Victoria park. 1870.
Thomson, John Millar, King's College, London. 1869.
Thomson, Jonathan, 136 West George street. 1869.
Thomson, Sir William, LL.D., F.R.S., Professor of Natural Philosophy, University of Glasgow, *President.* 1846.
565 Thomson, William, 80 Buchanan st. 1873.
Townsend, Joseph, 13 Crawford street, Port-Dundas. 1856.
Townsend, Robert, 128 Bishop street, Port-Dundas. 1865.
Turnbull, Andrew H., Dunard villa, Dowanhill. 1872.
Turnbull, John, 62 St. Vincent st. 1843.
570 Turnbull, J. Jos., 62 St. Vincent st. 1868.
Turner, William, 33 Renfield street. 1875.

Ure, John, Crown Mills, 68 Washington street. 1856.

Virtue, John, 63 St. Vincent cres. 1869.

Walker, Archibald, 4 Muirhead st. 1869.
575 Walker, John, Dalmarnock Dye Works. 1869.
Walker, Malcolm M'N., F.R.A.S., 45 Clyde place. 1853.
Walker, William, 12 Lime street, London, E.C. 1869.
Wallace, Wm., Ph.D., F.R.S.E., F.C.S., 138 Bath street. 1851.
Watson, Eben., A.M., M.D., Professor of Institutes of Medicine in the Andersonian University, 1 Woodside terrace. 1873.
580 Watson, George, Phœnix Office, 22 Exchange square. 1864.
Watson, James, 2 Florentine place, Hillhead. 1873.
Watson, Thos., 22 Exchange sq. 1869.
Watson, Wm. W., F.S.S., City Chambers. 1865.
Watson, William Renny, 16 Woodlands terrace. 1870.
585 Watson, Robert, 42 Hutcheson st. 1872.

Watt, Alexander, 67 Renfield street. 1870.
Weight, George P., C.E., Clutha Ironworks. 1875.
Weir, John, M.D., F.R.C.S. Edin., 25 Sandyford place. 1875.
Wenley, James A., 8 Lynedoch pl. 1870.
590 Westlands, Robert, 8 Howard st. 1869.
White, John, Scotstown and Slit-mills, Partick. 1875.
Whitelaw, Alexander, 87 Sydney st. 1855.
Wilson, Alexander, Hydepark Foundry, 54 Finnieston street. 1874.
Wilson, Daniel, 124 Bothwell st. 1872.
595 Wilson, David, 145 Ingram street. 1850.
Wilson, J. G., M.D., F.R.S.E., F.R.C.S.E., Professor of Midwifery in the Andersonian University, 9 Woodside crescent. 1856.
Wilson, J., 468 Gallowgate. 1870.
Wilson, J. Veitch, 116 St. Vincent st. 1874.
Wilson, John, 11 Woodside place. 1873.
600 Wilson, William, Holmhurst, Dowanhill gardens. 1870.
Wingate, P., Woodcroft, Partick. 1872.
Wingate, Wm., Jun., 12 Garthland st. 1865.
Wolfe, J. R., M.D., F.R.C.S.E., 18 Brandon place. 1872.
Wood, J. Muir, 42 Buchanan street. 1850.
605 Woodburn, J. Cowan, M.D., 257 Sauchiehall street. 1869.
Wright, S. H., M.D., C.M., M.R.C.P.E., Barony Hospital and Asylum, Barnhill. 1873.
Wright, Thomas, 128 Bothwell st. 1873.
Wünsch, Ed. A., 146 W. George st. 1863.
Young, Jas., F.R.S., Kelly, Wemyss Bay. 1852.
610 Young, John, M.D., F.R.S.E., Prof. of Natural History in the University of Glasgow, 13 Sardinia ter. 1866.
Young, John, Jun., Forth street, Port-Dundas. 1870.
Young, R., Castlehill, Pollokshields. 1873.
Young, Wm., Forth street, Port-Dundas. 1868.
Younger, Geo., 1 North Exchange court. 1874.
615 Yule, John, 23 Carlton place. 1869.

INDEX.

CONSTITUTION

OF

THE PHILOSOPHICAL SOCIETY

OF GLASGOW.

INSTITUTED 1802.

Non fingendum aut excogitandum, sed inveniendum, quid Natura faciat aut ferat.—BACON.

GLASGOW:
PRINTED BY BELL AND BAIN, 41 MITCHELL STREET.
1875.

RULES OF THE SOCIETY

As Amended in Session 1874-75.

CONSTITUTION.

I.

NAME OF THE SOCIETY.

The Society shall be called "THE PHILOSOPHICAL SOCIETY OF GLASGOW."

II.

OBJECTS OF THE SOCIETY.

The objects of the Society shall be to aid the advancement of the Mathematical, Physical, and Natural Sciences, with their applications, and to promote the diffusion of scientific knowledge.

III.

MEMBERS.

The Society shall consist of three classes of Members,—Ordinary, Corresponding, and Honorary.

Ordinary Members shall be such persons as are duly elected according to the Constitution of the Society.

Corresponding Members shall be persons not resident in Glasgow, who have rendered valuable service to the Society, or from whom important intelligence on scientific subjects may be expected.

Honorary Members shall be persons who have contributed in an eminent degree to the advancement of Science.

IV.

ORDINARY MEMBERS.

Candidates shall be proposed in writing by three Members; intimation of such proposals shall be given to the Society in the Circular calling the next Ordinary Meeting, at which they shall be balloted for, and shall be elected if more than four-fifths of the votes are favourable. The Secretary shall inform Members, by letter, of their election. Upon admission, every Member shall pay One Guinea as Entry-money, and One Guinea in addition as the first year's Annual Subscription; if he fail to comply with the terms of this Article within two months, his election shall be void.

Upon admission, each Member shall sign his name to the following Declaration, in a Book kept for the purpose:—

DECLARATION.—"*I hereby bind myself to observe and obey the Laws of the* PHILOSOPHICAL SOCIETY OF GLASGOW."

The Annual Subscription to the Society shall be One Guinea, due on the first of November. Members whose Subscriptions are in arrear shall not have the power to vote on any question, nor to use the Library, nor be entitled to receive the printed *Proceedings* of the Society.

Members shall be held liable for their Annual Subscriptions until they have given to the Secretary written notice of their resignation.

Members becoming non-resident, and not in arrear, shall, on giving notice in writing to the Secretary, become entitled to resume their position as Ordinary Members whenever they return to Glasgow, upon payment of the current year's Subscription.

Original Members of the Society, or old Life Members, are liable to the payment of 5*s.* per annum.

Members who have paid their Entry-money may compound for their Annual Subscriptions by a single payment of Ten Guineas.

V.

CORRESPONDING MEMBERS.

Corresponding Members shall be recommended by a majority of the whole Council, and shall be balloted for in the same manner as Ordinary Members.

Corresponding Members shall not be required to pay either Entry-money or Annual Subscription. They shall each receive a copy of the *Proceedings* of the Society.

VI.

HONORARY MEMBERS.

The number of Honorary Members shall not at any time exceed twenty; not more than three to be elected in any one year.

Honorary Members shall be recommended by a majority of the whole Council, and shall be balloted for in the same manner as Ordinary Members. They shall be liable to no payments, and shall each receive a copy of the *Proceedings* of the Society.

VII.

OFFICE-BEARERS.

The business of the Society shall be conducted by a Council,

consisting of the President, Ex-Presidents, Three Vice-Presidents, Presidents of Sections (*ex officio*, and if otherwise eligible), Librarian, Treasurer, Secretary, and Twelve other Members, to be elected as hereinafter prescribed.

VIII.

President and Vice-Presidents.

The President shall take the Chair on all occasions when present. In absence of the President, one of the Vice-Presidents shall take the Chair; when the President and Vice-Presidents are absent, any Member may be voted into the Chair. In case of an equality of votes, the Chairman shall have a casting vote in addition to his deliberative vote. The President shall be a member *ex-officio* of all Committees.

Presidents on retiring from office shall be Honorary Vice-Presidents so long as they continue Members of the Society.

IX.

Librarian.

The Librarian shall have charge of the Books belonging to the Society, and shall keep a Catalogue of them, and a register of their circulation among the Members. He shall consult the Library Committee in regard to the purchasing of all Books. He shall levy the fines incurred by breach of the Library Regulations, and pay over the same to the Treasurer a week before the annual accounts are made up. The Librarian shall have the assistance of a Sub-Librarian, duly appointed by the Council. The Librarian shall present to the Annual General Meeting a list of the additions made to the Library during the past year. The list shall be printed in the *Proceedings* annually.

Regulations for the Management of the Library.

1. The Books may be exchanged each lawful day, at such hours as the Council may from time to time determine.

2. Books shall not be taken from the Library until the Borrower sends a written order, or signs his name for them against the Entry in the Register of Books in Circulation.

3. No reader shall be allowed more than one volume at a time of Books that have been less than three months in the Library, or three volumes at a time of books that have been more than three months in the Library.

4. The time allowed for reading the books, and the fines for keeping them too long, shall be as follows:—

AFTER ENTRY.	TIME ALLOWED.	FINES IF KEPT LONGER.
First Month, . . .	Three Days, .	One Penny per Day.
Second and Third Months,	Seven Days, .	Threepence per Week.
After the Third Month, .	Two Weeks, .	Twopence per Week.

5. If any Member retains a volume beyond the times above specified, the Librarian shall require him, in writing, to return it immediately; and if he does not comply, the Society may replace it, charging him not only with the price, but also with the fines due for not returning it. If the volume belongs to a set of books, the whole set must be replaced, provided the volume wanting cannot be got apart. If any book is damaged when returned, a fine equivalent to the injury, as the Council shall determine, must be paid, and if injured so as to be unfit for use, it must be replaced by a complete copy.

6. If a reader who has incurred fines refuses to pay them, his right to read books from the Library shall be suspended. The fines shall be paid to the Librarian, or his substitute.

7. None but Members of the Philosophical Society shall be entitled to borrow the books belonging to the Society's Library.

8. Members engaged in drawing up papers to be read before the Society may have an extra number of volumes, and be allowed a longer time to read them, upon producing an order to that effect from the Secretary of the Society, or the Secretary of one of the Sections.

9. New books and periodicals shall lie on the Library table for at least a fortnight before being given out. Rare and valuable books to be divided into two classes; one class to be marked "Not to be given out," and the other to be given out only on special application in writing to the Librarian.

10. All books shall be called in for inspection a week before the Annual Meeting. The names of Members not complying with this Rule shall be read at the Annual Meeting and exhibited in the Library.

11. Any contingency not provided for in these Regulations shall be submitted to the Council, and their decision shall be final and binding on all concerned.

X.

TREASURER.

The Treasurer shall have in charge the Funds of the Society, and shall receive all Payments due to the Society, either personally, or by his substitute, or by a guaranteed Collector duly appointed by the Council. Whenever the sum in his hands amounts to Twenty Pounds, he shall deposit it in one of the Glasgow Banks, in name of the President and himself conjointly. He shall pay such sums as may be ordered by the Council, and shall keep an account of all his intromissions in the Society's General Cash-Book, which account shall be balanced annually, on the 31st October, and be submitted to the Annual General Meeting, having been previously examined, with the Vouchers, by two Auditors (who shall not be Members of the Council) appointed by the Society at the first Meeting in November. The Treasurer shall also keep a Register of the Names of the members of the Society, which shall be presented at the Annual General Meeting, together with an Inventory of all the Property (except the Library) possessed by the Society.

XI.

SECRETARY.

The Secretary shall record the Minutes in books kept for the purpose. He shall also conduct the Society's general correspondence, act as Secretary to the Council, and edit the *Proceedings*, subject to the approval of the Council. He shall be under the control of the Council; and shall receive such a Salary as the Council may determine. He shall be a Member *ex-officio* of all Committees of Council.

XII.

MEETINGS OF THE SOCIETY.

The REGULAR MEETINGS shall be held in the Society's Rooms on alternate WEDNESDAY evenings, from the beginning of November till the end of April. The Secretary shall announce these Meetings by Circular addressed to all the Members of the Society residing in the United Kingdom, the Circular to contain a copy

of the Minutes of the previous Meeting, notices of motion, and other business to be brought before the Meeting announced. Twenty Members shall constitute a quorum. The Chair to be taken at Eight o'clock, when the business shall proceed as follows:

1. The minutes of the previous Meeting to be read and confirmed, and signed by the Chairman.
2. New Members to be admitted.
3. Proposal of New Members.
4. Papers to be read.
5. Announcement of Ballot for New Members.
6. Motions and General Business to be disposed of, commencing not later than 9·40 P.M.

The Society may also hold occasional EXTRA MEETINGS, at which lectures shall be delivered on questions of scientific interest; and to those Meetings persons not being members of the Society may be admitted under such regulations as the Council may deem expedient.

EXTRAORDINARY or SPECIAL MEETINGS may be called by the Council when they consider it proper or necessary; and must be called by them on receipt of a requisition from ten Members specifying the business to be brought before such Meeting; twenty Members to constitute a quorum should the Meeting be held during the session, and thirty should it be held during the recess.

A GENERAL MEETING of the Society shall be held ANNUALLY on the third WEDNESDAY in November, or as near that day as may be, due intimation of which shall be communicated by the Secretary to all the Members of the Society.

At this General Meeting—

The Council shall give in a Report on the State of the Society.

The Treasurer shall exhibit an audited Statement of the Funds of the Society.

The Librarian shall report on the State of the Library.

Thereafter, the Society shall proceed to the filling up of vacancies in the Council, in the following order:—

1. Election of President.
2. Election of Vice-Presidents.
3. Election of Librarian.
4. Election of Treasurer.
5. Election of Secretary.
6. Election of Members of Council other than the preceding Office-Bearers; four of the twelve retiring by rotation, and four being elected in their place.

XIII.

Motions and Voting.

Votes for the election of Office-Bearers and the admission of Members to be given by ballot; all other votes *vivâ voce.*

Any motion may be carried by a simple majority of votes: excepting for the admission of Members, when one-fifth of the votes tendered shall exclude; and for the altering of, or adding to, the Rules.

A motion for altering, annulling, or enacting Rules, shall not be adopted until it has been approved of at two successive Meetings of the Society in the same Session, by the votes of two-thirds of the Members present. Should the motion be negatived, it is lost for that Session. But no vote shall be taken on any such motion unless it has been previously submitted to the Council.

No Motion shall be entertained unless notice of it has been given at a previous Meeting.

XIV.

Sections.

The Society may comprise the following or other Sections :—

A. Archæological Section.
B. Architectural Section.
C. Chemical Section.
D. Geological Section, including Mineralogy.
E. Mathematical and Physical Section, including Mechanics and Engineering.
F. Physiological Section, including Natural History.
G. Sanitary and Social Economy Section.

Each Section may meet separately, and read and discuss papers, and otherwise transact business in accordance with the objects of the Section. It shall not be competent for any Section to take public action by memorial, deputation, or otherwise, without the sanction of the Society. The Members of the Society may attend any of the Sectional Meetings. Each Section may have Associates, for each of whom the Section shall pay to the Treasurer of the Philosophical Society Five Shillings annually. Associates shall not be entitled to the privileges of the Society, but may consult the books—in the Library.

XV.

"Proceedings" of the Society.

The *Proceedings* of the Society shall be published annually: they shall also be issued in sheets during the Session, and sent to those Members who shall indicate to the Secretary, in writing, their desire to receive them. The *Proceedings* shall consist of a

selection from the Papers which have been read at the meetings of the Society and its Sections, or of abstracts of these Papers,—such selection to be made by the Council. The authors of Papers published by the Society shall receive Thirty copies free of expense.

The Council shall have power to reject any communication which they may deem unsuitable for the Society.

XVI.

Property of the Society.

The Property of the Society shall be vested solely in the Ordinary Members, and be under the management of the Council.

The Society shall not pay any Dividend, Gift, Division, or Bonus in money to Members from its funds.

XVII.

The Council.

Ordinary Meetings of Council shall be called by a Circular, intimating the business to be brought forward. Extraordinary Meetings of the Council may be called by the President, at his own discretion; or shall be called upon a requisition presented to him (or, in his absence, to one of the Vice-Presidents), signed by five Members of Council. At a Meeting of Council, five shall constitute a quorum. The Secretary shall record the proceedings in a Minute-book. A list of the Members of all Committees of Council shall be printed in the first Circular after their appointment, and inserted in the *Proceedings*.

The Council shall administer the Funds of the Society, by defraying necessary charges, printing the Society's *Proceedings*, and purchasing books, models, or instruments. It shall not be competent for the Council to spend money on any other object, without the consent of the Society, to be obtained at two successive Meetings.

Members of Council, except Ex-Presidents, shall each hold office for not more than three years; and every retiring Office-Bearer shall be ineligible to the office from which he retires, until he has been one year out of it, excepting the Librarian, the Treasurer, and the Secretary, who may be re-elected.

Vacancies arising during the currency of a year may be filled up, *ad interim*, by the Council, if they deem it expedient. Members so appointed shall hold office till the next ensuing Annual Meeting, when the Society shall supply the vacancies for the remaining time of the original Members' terms of office. Those appointed to vacancies in this manner shall be eligible for immediate re-election if their period of service has not extended to two years.

DATE DUE
